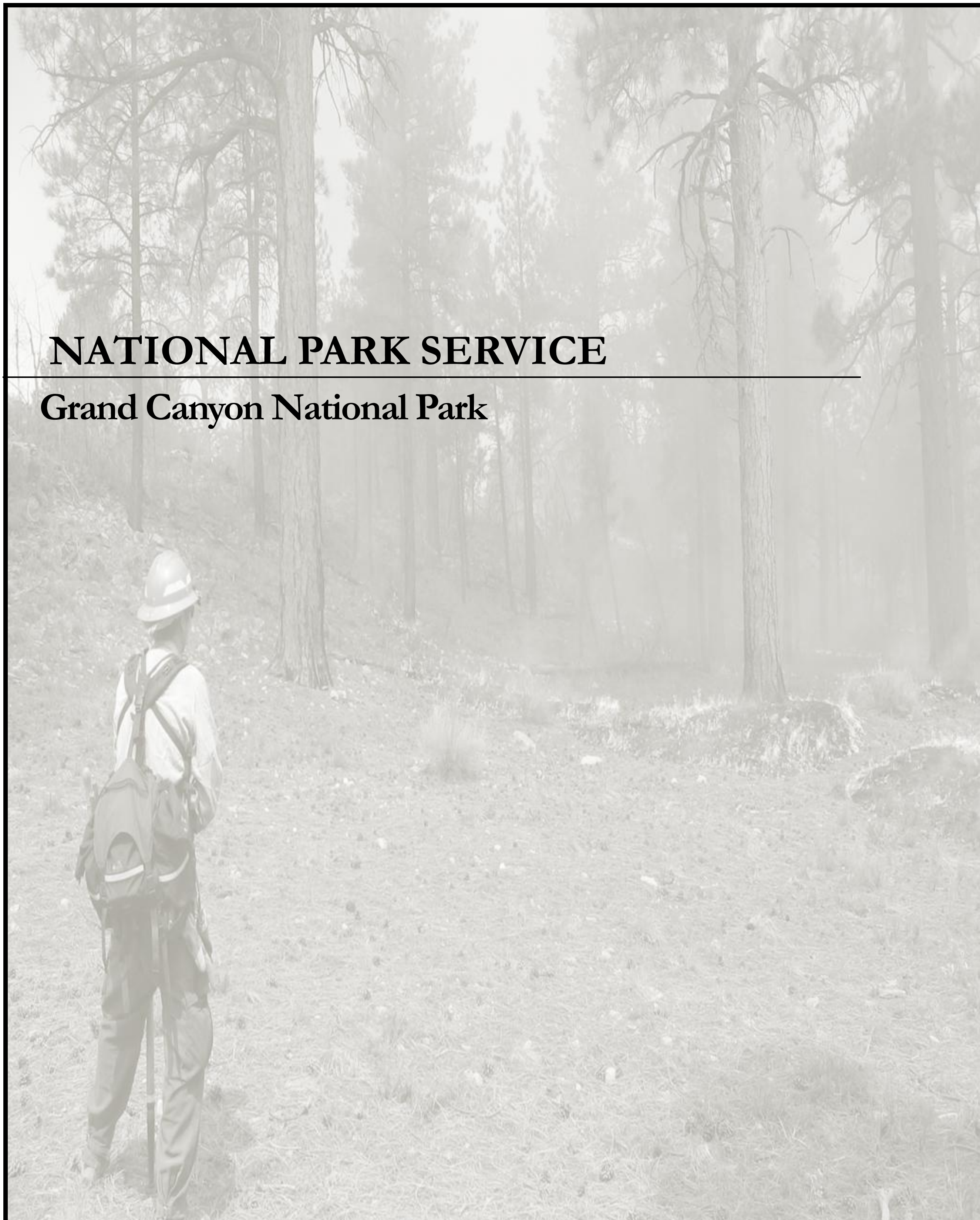


NATIONAL PARK SERVICE

Grand Canyon National Park

FIRE ECOLOGY ON THE RIM

Table of Contents

Part One: Background Information

Part Two: Field Experience

Table of Contents

Part Three: Conclusion

Table of Contents

Welcome Letter

Welcome to *Fire Ecology on the Rim*! We hope this program will introduce students to the basics of fire ecology and also give them valuable field experience. There are many ways to use the materials in this program, such as a stand-alone teaching unit in a classroom or as part of a Grand Canyon filed trip. Feel free to pick and choose what works best for you!

The Table of Contents is divided into three parts. **Part One: Background Information** offers some information and activities to help introduce fire ecology. **Part Two: Field Experience** outlines field monitoring protocols to be used at Grand Canyon National Park. **Part Three: Conclusion** offers ways to analyze field data and further learning about fire ecology.

Part One: Background Information is broken into three sections: *Introduction*, *Fire Basics*, and *Fire Ecology at Grand Canyon National Park*. Within these sections are documents containing background information on important fire ecology topics, as well as activities that support learning about these topics. The activities should not be used in isolation, but rather after a specific topic has been introduced.

Part Two: Field Experience should be preceded by background information about fire. Within this section are activities designed to introduce tools used by the fire trade. Also in this section are field protocols modeled after those used by Grand Canyon National Park fire monitors. The data collected by students using these protocols may be given to Park resource managers, so it is important to follow the protocols as closely as possible. Data sheets for each protocol are included in this section.

Part Three: Conclusion includes worksheets for field data analysis and other wrap-up activities. Also in this section are review activities such as games.

Why Study Fire?

This program will focus on studying the chemical reaction of fire, fire behavior, and fire's effects on the landscape. The goal is to encourage public understanding of the potential benefits of fire. Many people think that fire can only bring about negative consequences, but often it can bring about good and desirable effects!

For example, the goal of many prescribed burns is to remove excess fuels that have built up on the forest floor after years of suppressing wildland fires. By studying the amount of fuel available to burn before a fire, then re-measuring the amount of fuel left in that area after a fire, monitors can assess whether the goal of fuel reduction has been met. Other goals that fire can meet include:

- Controlling insect pests
- Controlling invasive (non-native) species
- Replenishing soil nutrients by spreading ashes of burned plant matter
- Opening up the forest floor so native grasses and flowers can grow
- Helping fire-dependent species grow
- Improving wildlife habitat

Fire monitors are some of the people who study fire. By studying fire, fire monitors can come closer to understanding what types of environmental factors bring about 'good' fires, and what types bring about undesirable fires. Some environmental factors that fire monitors study in relation to fire are:

- Wind speeds
- Temperatures
- Relative Humidity
- Topography
- Types of fuels (plant material) available to burn

For example, fire monitors might take wind speed measurements and then observe how a fire burns. In the future, that observation data can help fire planners know when conditions are desirable to light a prescribed fire, or when it is desirable to suppress a wildland fire.

Fire is a natural phenomenon that cannot be completely controlled. But, that doesn't mean we should stop trying to understand it. This program should offer some tools to help you better understand fire and to pass that understanding on to others.

Introduction

Fire History at Grand Canyon National Park

Historically, low intensity surface fires have swept across arid Southwest forests. Analysis of fire scars on trees and on the landscape shows that such fires were occurring at least hundreds of years ago, if not thousands. Before European settlers arrived in the Southwest, Native American populations used fire for land management (for example, to create bison grazing land) but did not create dramatic landscape-level change with fire. Tree scars show that in ponderosa forests, the *fire interval* was between 5-10 years, meaning that low intensity fires would occur often.

When European settlers began coming to the Colorado Plateau in the late 1800s and early 1900s, drastic changes started to take place. New settlers in the region thought of fire as a force of evil on the land and people, and did not realize its ecological benefits. The United States Forest Service and other land management agencies decided in the early 1900s that fire suppression was the best policy to adopt, and soon the *Ten o'clock rule* was applied to public lands. This policy stated that every fire, naturally ignited or not, must be extinguished by 10 A.M. the following day. This policy caused a huge amount of land to go unburned. During this time, forest land was also being logged and used for cattle grazing. Both activities, coupled with the absence of fire, lead to striking landscape changes in the Grand Canyon region. In some cases, land once forested became grasslands and desert. In others, land became overloaded with fuels historically cleaned out by surface fires.

In the 1930s, some ecologists realized that, along with other activities, suppressing fire could potentially be changing forests for the worse. However, it wasn't until the late 1960s that fire management policy began to reflect that realization. At that point, forests were so overloaded with fuels that instead of low surface fires, *stand-replacement crown fires* were beginning to happen more often. Crown fires can be landscape-changing events, especially in the ponderosa pine forests of Grand Canyon. A very large fire can kill trees instead of restoring small trees and woody debris to more natural levels.

Although today fire planners in the park now use prescribed fire to help remove excess plant matter from forest floors (such as pine needles, shrubs, and downed logs), years of suppression are still obvious in forests that are overloaded with small trees and woody debris historically burned and kept at low levels by surface fires.

Fire Basics

What is Fire?

Fire is a chemical reaction between fuel and oxygen. Heat is necessary to ignite the reaction. Once a fire has been started, it creates enough heat as a by-product to keep igniting new fuels.

In nature, fuels can be pre-heated by the sun. This can make them more likely to ignite, either by human error (like a dropped cigarette or unattended campfire), or by lightning. Fuels themselves are abundant, especially in forests that have not burned in recent years. Oxygen is, of course, readily available in the air. The air we breathe has about 21% oxygen in it.

Burnable things are all around us. Why isn't more stuff on fire?

Take a look at the fire triangle. It shows the three necessary components for fire's chemical reaction: Oxygen, Heat, and Fuel. If you take away one of the three legs of the triangle, it collapses; likewise, if you take away one of the three components of fire, it can't survive. Often all that's missing from the equation is heat! Even so, without all three there is no fire.

Fire's Chemical Reaction

Fire's chemical reaction looks like this:

$$C_6H_{12}O_6 + 6O_2 + \text{Heat (ignition source)}$$
$$\downarrow$$
$$6CO_2 + 6H_2O + \text{Heat} + \text{Light}$$

Simplified, it looks like this:

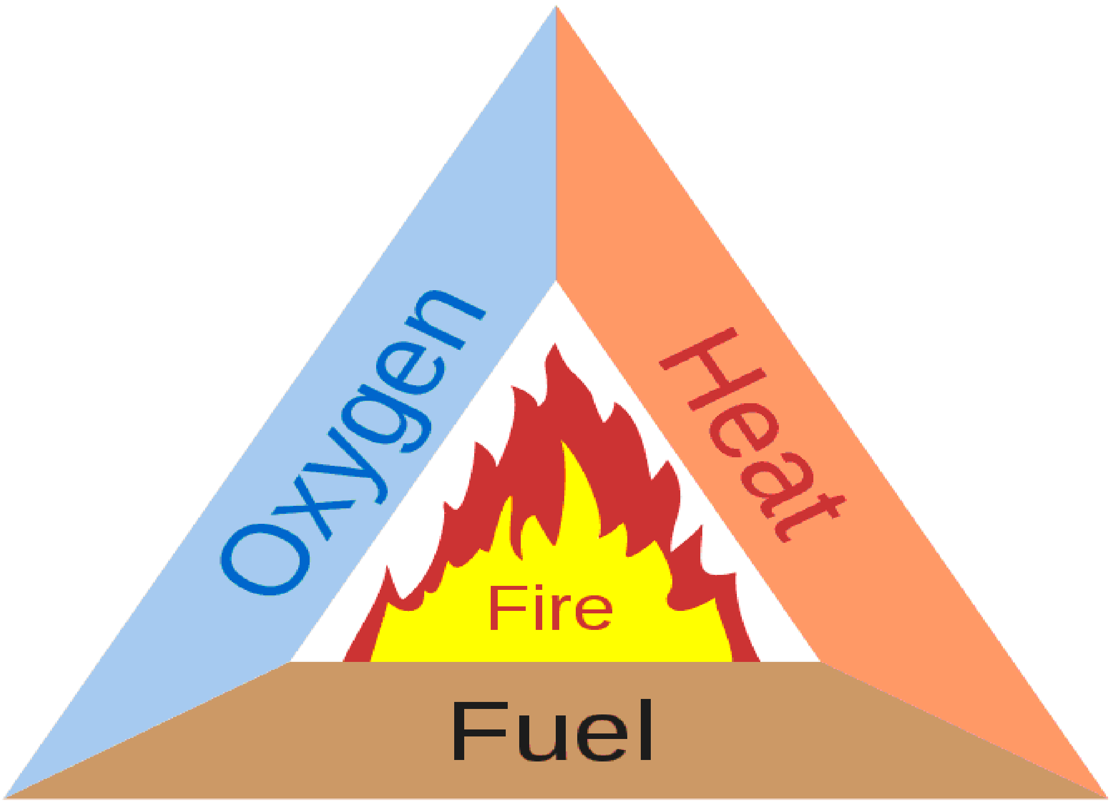
Carbohydrate + Oxygen + Heat

↓

Carbon dioxide + Water Vapor + Heat + Light

Where *carbohydrate* is *fuel*.

The Fire Triangle



Fire Behavior: Weather, Fuels, and Topography

When fire monitors study fire behavior, they observe three key environmental factors:

- Weather
- Fuel
- Topography

Weather

Fire monitors measure certain weather conditions to predict how a fire might behave. Specifically, monitors measure wind speed, temperature, precipitation, and *relative humidity*.

- Wind speed is a very important factor in fire monitoring. Wind can spread fire by blowing flaming material to new fuel. Wind can dry fuels and prime them for igniting. Wind also brings fresh supplies of oxygen to fire, at the same time feeding it and spreading it.

- The ambient temperature will determine how quickly fuels ignite. Hot temperatures indicate a high level of *solar radiation*, which can heat fuels and prime them for igniting more quickly.

- Knowing whether precipitation is in the forecast can help fire monitors decide when to allow burning and when to suppress it.

- Measuring *relative humidity* tells fire monitors the amount of moisture in the air. Higher air moisture levels can dampen fuels. Therefore, a fire on a day with high relative humidity might spread more slowly, because fuels need to dry out to ignite. Likewise, fires may burn less intensely at night: because the sun isn't heating the air, relative humidity is often higher then.

Grand Canyon National Park is very dry for most of the year with low relative humidity. It is also warm for much of the fire season, which runs from spring to fall. The Park's high elevation means the sun's rays are stronger, which in turn makes fuels hotter and drier. Heavy storms during spring and summer bring lots of lightning and sometimes *virga*, which is rain that falls but does not reach the ground (and still brings lightning strikes). The Colorado Plateau receives the most lightning strikes per square mile of any place on earth. Under these conditions, lightning strike ignition can be common.

Fire Behavior: Weather, Fuels, and Topography

Fuel

Fuel refers to burnable materials. In a forest setting, fuels are anything from *duff* (partially decomposed organic matter) and *surface litter* (fallen leaves, needles, pinecones) to full trees. Fuels can be classified by size, and also as dead or living. Some fuel characteristics that can influence fire behavior are:

- *Fuel loading*- the amount of burnable material.
- Fuel distribution- how fuels are situated on the ground (that is, are they clumped? Are they mostly *aerial fuels* or *ground fuels*?)
- Fuel moisture- how much water is in the fuel (recorded as a percent of the total water a fuel could hold)
- Fuel size and shape- for example, small, flat fuels dry out faster and ignite more readily than large, round fuels

Many things can influence how a fuel will burn. Moisture has a big affect, because wetter fuels must first dry out in order to ignite. This is why dead fuels burn faster than live ones. Density also helps determine how fuels will burn. Fuels that are close together will more easily catch fire than those separated by swaths of unburnable material, such as rocks.

Though ponderosa pine is well adapted to frequent fires, *snags* (standing dead trees) and young pines can act as *ladder fuels* and ignite ponderosa crowns. In a surface fire, flames don't frequently reach the height of many ponderosa needles, but a shorter tree or dead tree can act as a ladder by bringing the flames up to the needles of other trees.

Types of Fuel:

Surface Fuels

Needles or leaves
Grass
Small dead wood
Downed logs
Stumps
Low shrubs

Ladder fuels

Anything that provides a pathway to the canopy- for example, young trees

Aerial Fuels

Tree branches and crowns
Snag

Fire Behavior: Weather, Fuels, and Topography

Topography

Topography describes land shape. It can include descriptions of:

- Elevation- height above sea level.
- *Slope*- steepness of the land.
- *Aspect*- the direction a slope faces (e.g., the south side of canyon has a north-facing slope).
- Features- such as canyons, valleys, rivers, etc.

Grand Canyon National Park is characterized by the high elevations of the Colorado Plateau, the Canyon itself, and the rolling elevation changes that happen along the rim. These topographical features can help or hinder the spread of fire. For example, the canyon acts as a great natural fire break. If a fire burned up to the rim, it could fall down into the canyon a ways but then it would probably put itself out. Why? There are hardly any good fuels below the rim. This lack of fuel and wide gap of open space keeps fires from rim-hopping. Drainages and other rocky areas with little vegetation can act as fire breaks, as well.

Beyond the shape of the land, it is also important to consider elevation, slope, and aspect. Elevation and aspect can determine how hot and dry a given area will be (for example, higher elevations will be drier but colder than low ones, and a north-facing slope will be slower to heat up or dry out).

Slope can determine how quickly a fire will move up or down hills. For example, if a fire ignites at the bottom of a steep slope, it will spread much more quickly upwards because it can pre-heat the upcoming fuels with rising hot air, and upward drafts are more likely to create *spot fires*.

How Fire Burns

Here are two ways fires commonly burn at Grand Canyon:

Surface fires have visible flames and ignite leaf litter, downed wood, and other ground level fuels.

Crown fires have visible flames and burn through the top layer of foliage on a tree (its *canopy*, or *crown*).

Activity: Weather and Fuels

Lesson Overview

Students will watch a demonstration and make suggestions on how to break the fire triangle. Then they will conduct a weather and fuels observation activity.

Lesson Objectives

Students will identify the three components of the fire triangle. They will learn what weather observations fire monitors make, and how weather and fuels influence fire behavior.

Materials

- One non-flammable bucket **per group**
- Selection of plant material (a few handfuls of each type):
  - dead, dry pine needles, dry small twigs
  - green pine needles and fresh, green small twigs
  - semi-burned materials
- Box of kitchen matches
- Weather monitoring equipment:
  - sling psychrometer
  - anemometer
- Stopwatch
- Water in spray bottle
- Non-flammable small hand trowel or other tool
- Non-flammable cover for pan that will block out oxygen
- Rag or old towel for drying
- Extra pan or bucket for used plant material
- Fire Triangle Graphic
- Chemical Reaction Graphic
- Safety equipment (glasses, mitts, fire extinguisher)
- Journals, clipboards, and pencils

Activity Length

1.5 Hours

Activity: Weather and Fuels

……………………

Procedure

<u>**WARNING:**</u> *This lesson requires igniting plant material under controlled conditions. Please conduct this lesson outside in a non-flammable area (such as a large patch of pavement away from dry plant material). Also, a* ***CLASS-A FIRE EXTINGUISHER*** *and* ***PROPER ADULT SUPERVISION*** *must be present during this lesson.*

Fire Triangle Demonstration:

1. Introduce the fire triangle by asking students: What needs to be present for a fire to occur? Use the Fire Triangle Graphic to reinforce.

2. Introduce fire's chemical reaction- use the Chemical Reaction Graphic and relate it to the fire triangle. (Each component of the fire triangle is present in the chemical equation.)

3. Discussion questions:
a. What can be a source of fuel in a wildfire or prescribed fire? (plant material) What can be a source of heat? (lightning, sun)
b. Where is the oxygen coming from? (it's all around)

4. If not already outside, move to a safe location for this activity. Review fire safety with class. Confirm that weather conditions are appropriate to continue the lab.

5. Set up a pan so students can see inside of it. Place two handfuls of dead, dry plant material into the bucket and spread it out slightly so it is not in one big pile. Have the **cover, spray bottle, and trowel** ready.

6. Either you or a volunteer can ignite the fuel in one corner of the tray. Whoever is igniting should be wearing safety equipment. Once the flame is established, ask students how the fire triangle can be broken to put this fire out. The first guess might be to spray it with water, to which you could respond:
Question: We all know that water puts out fire, but how does water break the fire triangle? (removes oxygen, removes heat)

7. Once it is completely extinguished, move the burnt plant material into the extra pan or bucket. If water was sprayed in the pan, dry it out. Repeat this procedure until all of the tools have been used.

Activity: Weather and Fuels

Question: How does covering a flame break the fire triangle? (removes oxygen)
Question: How does spreading out the plant material/making a “fire line” break the fire triangle? (removes fuels)

Group Activity:
1. Divide class into four groups. Pass out the materials as follows:
- Group one: a bucket with two handfuls of dry fuels
- Group two: a bucket with two handfuls of green fuels
- Group three: a bucket with one handful of green fuels and one handful of dry fuels
- Group four: a bucket with one handful of dry fuels and one handful of leftover semi-burnt fuels from the other groups.

The fuels should be spread out slightly in the bucket so they form a continuous mat (no fuel breaks) but are not clumped. Each group will need their weather monitoring tools and journals and pencils. Have the kitchen matches and stopwatch ready.

2. Have each group spend a few minutes taking weather observations and recording them in their journal.

3. Ask students to individually complete the hypothesis section using the weather information they have gathered.

4. Have groups set up their bucket so that everyone in the class can see it.

5. Have the stopwatch ready: ask the first group to ignite their fuels starting in the center of the pile (to keep the conditions controlled). Time how long it takes the fuel to burn completely and extinguish itself. Repeat for other groups. The group who was assigned a mixture of burned and unburned fuel will be the last to ignite. They should take half a handful from each of the dry and green fuels pans. Have students record the official burn times in their journal. If it takes more than 60 seconds for fuel to ignite, count this as unburnable (e.g. the green fuels).

6. Clean up, discuss, and have students individually complete their journal work. Discussion points:

a. Which group’s fuels burned the fastest? Why?

b. Why do green fuels burn more slowly? (Green fuels have higher moisture content and must first dry out in order to burn.)

c. How did the partially burned fuel burn in comparison to the other fuels?

Handout: Weather and Fuels

Making Predictions

1. Sling Psychrometer-Relative Humidity: ________________
   What does this reading mean?

2. Anemometer- Wind Speed: __________________
   What does this reading mean?

3. Which pan's fuels will burn the fastest? Rate from one (fastest) to 4 (slowest) how each pan will burn:

   a. mix of dry and green ________
   b. mix of dry and semi-burnt ________
   c. all green fuel ________
   d. all dry fuel ________

4. Why did you rate the fuels that way?

5. Based on today's weather conditions, would you suggest lighting a prescribed fire? Why or why not?

6. What do you think would happen if a prescribed fire was lit today? Be specific when talking about fire behavior.

Handout: Weather and Fuels

Experiment: Take turns as groups. Light the fuels from the bottom right corner and record the time it takes for the fuels to burn out.

7. Times to completely burn different fuels (if it takes over 1 minute to ignite count as unburnable)

   a. mix of dry and green ________
   b. mix of dry and semi-burnt ________
   c. all green fuel ________
   d. all dry fuel ________

Results

8. Compare your prediction on question 3 to your results. Describe what you found. (Were you right? If results were different than predictions, how could you explain the difference you observed?)

Activity: Topography and Fuel Density

Lesson Overview

Students will hypothesize how well each matchstick forest will burn and why. Students will then ignite matchstick fires and observe results.

Lesson Objectives

Students will understand how topography affects fire behavior.

Materials

- A non-flammable aluminum pan **per group**
- One large box of kitchen matches **per group**
- Safety equipment (glasses, gloves, fire extinguisher)
- Journals and pencils
- Modeling clay or salt dough*- enough for each group to have two or three large handfuls
- Stopwatch
- One box of tin foil
- Rulers

Activity Length

1 Hour

Procedure

__**WARNING:**__ *This lesson requires igniting many matches under controlled conditions. Please conduct this lesson outside in a non-flammable area. Also, a **CLASS-A FIRE EXTINGUISHER** and **PROPER ADULT SUPERVISION** must be present during this lesson.*

1. Arrange students into groups. Each group should have no more than 4 people. Assign each group a terrain type. Depending on how many groups there are, choices can include:

Hilly	Flat
Canyon	Downhill steep
Uphill steep	Downhill not steep
Uphill not steep	Etc.

Activity: Topography and Fuel Density

2. In addition, assign each group a fuel density level: dense (20 or more matches per square inch), moderate (10-19 matches per square inch), or sparse (0-9 matches per square inch). Groups can also experiment with "dead and downed fuels" (broken matches or matches not stuck into the clay). It doesn't matter how density is assigned as long as there is variety across the groups.

Variation: If desired, assign all groups to one terrain type and vary the density, or assign all groups one density and vary the terrain type.

3. Give students time to create their matchstick forest. They will need to first sculpt their clay into the assigned terrain (using tin foil to fill in gaps or create slope if needed). The surface area of the clay should be about 8" x 8". Next, they will need to stick matchsticks into the clay to create the assigned density. Have them use the rulers to check surface area and density.

4. Have students write descriptions of their forest in their journals.

5. Students should now predict how their forest will burn. They can write predictions in their journals.

6. Have the stopwatch ready. Each group should light their forests one at a time, so that the rest of the class can see. Time the burn from the ignition of the first match in the forest.

7. Each group should record observations about their own fire in their journals.

8. Compare burn times and discuss.

Discussion Questions:

a. Why did some forests burn faster than others?

b. What topographical aspect seemed to make the most difference in burn time? (Slope, aspect, features, etc.)

*Salt Dough Recipe

- 1 cup of salt
- 2 cups of flour
- 3/4 to 1 cup of lukewarm water

Mix salt and flour. Add water a little at a time until a ball forms. Knead for a few minutes.

Handout: Topography and Fuel Density

1. Terrain:

Percent grade slope?

2. Density:

Average trees per square inch?

Dead or downed fuels present? Lots Some Few None

3. Uniformity of trees? Very uniform Somewhat uniform
Random

4. Make a hypothesis about how your forest will burn (does not have to be time-specific).

5. Where will you light your forest from? Be specific.

6. Observations about your fire:

7. Response to your hypothesis:

Unplanned vs. Planned Wildland Fire

Unplanned Wildland Fires are like any other natural phenomenon: humans cannot control when, how, or where they start. In the past, many wildfires were suppressed immediately. Now, some naturally occurring fires are allowed to burn *if* fire monitors determine that the conditions are safe. At Grand Canyon National Park, most fires not ignited by fire staff are ignited by lightning. During monsoon season, huge storms sweep over the park and bring a lot of lightning. If you look around at the ponderosa pines in the park, you will see many of them have lightning scars. Not all lightning strikes start a fire, but some do, and these fires start out classified as *Unplanned Wildland Fires*.

Unplanned wildland fires can also be started by humans. Campfires that are not fully extinguished, lit cigarettes thrown out of car windows, and other human errors can start an unplanned fire.

Prescribed or Planned Fires are fires ignited under certain conditions with specific goals in mind. Fire planners do not just walk into a forest and decide to light a fire because they think it needs to be lit. Based on lots of past weather, topography, and fire behavior data collection, fire planners write a *prescription* to burn a certain area. This prescription must specify the conditions under which ignition is allowed: without the right conditions, ignition cannot happen. For example, prescriptions must contain information about temperature, relative humidity, wind, and predicted fire behavior. Also, the prescription must specify the goal of the burning. At Grand Canyon National Park, oftentimes that goal is *fuel reduction*. Fuel reduction means removing dead plant matter from the forest floor. This can restore the ecosystem to more natural conditions and reduce the possibility of a fire with undesirable effects. Other considerations when planning a fire include recreation site closures and the effect the fire may have on wildlife and cultural sites.

Fire on the Landscape

When fire sweeps an area, it affects all parts of an ecosystem:

- Plants
- Animals
- Soil
- Water
- Air

Plants

At the Grand Canyon, one of the most fire-affected plant ecosystems is the ponderosa pine forest. These forests have evolved over thousands of years to become adapted to relatively frequent fires. Historically, low intensity surface fires burned through ponderosa pine forests on the Colorado Plateau. This killed many pine seedlings and kept them from crowding out the forest and competing for resources with larger trees. These historic low level fires also enriched the soil by burning small fuels, such as grasses and shrubs, and scattering the minerals in the ash on the forest floor. This soil enrichment allowed for small plants to continuously grow in the forest understory without depleting the soil- it was like spreading a periodic layer of natural fertilizer. By regenerating the soil's nutrients, low intensity fires ensured the abundance of native grasses that were important for foraging animals. Non-native plants would be at a disadvantage because the conditions for native plants would be ideal, and non-native growth might be slowed by frequent burnings. Before human settlement, therefore, low intensity fires helped keep the forests' plant populations healthy and balanced.

Since humans began actively suppressing fires in the Grand Canyon area, ponderosa pine forests have become more heavily wooded with dense thickets of young trees. Also, a lack of fire has created a build-up of dead plant material on the forest floor. This means that the ideal low intensity fire is sometimes not possible now. Higher intensity fires resulting from greater fuel loads can burn too hot and destroy plant seeds as well as soil, and kill large fire-tolerant ponderosas by burning up their crowns.

Animals

How fire will affect animals depends on the type of fire and the type of vegetation. Where there are lots of fuels present and the potential for a high intensity fire, more animals are likely to be killed if that area burns. This applies especially to invertebrates and micro-organisms, because they are less able to flee fires or protect their eggs. Generally, larger mammals and birds aren't killed in fires because they are able to escape, and smaller mammals are able to burrow under the soil. In the case of a low intensity fire, burrowing usually lets small mammals live because heat levels are not too intense. In the case of a high-intensity fire, burrowing animals might die from high soil temperatures.

Low intensity fire can release nutrients into the soil which foster plant growth. Once animals eat this new nutrient-rich plant growth, they benefit from ingesting those additional minerals. Some animals don't even wait for the new plants to grow: white-tailed deer have been observed eating charred tree bark after a fire!

After a fire, animals that can be flexible with their diet, shelter, and movement patterns thrive. Fire often creates a varied, mosaic-like burn pattern that provides diverse vegetation. For example, new foraging areas might be opened up for deer and elk once a fire clears understory fuels.

Fire can have two very different effects on insects. First, high intensity fires may destroy the sap that keeps insects (like the bark beetle) from burrowing into tree bark. However, burning could reduce the food sources available to insect populations over the course of time (by eliminating weak trees and dead wood). Whether each of these effects is positive or negative depends on if the insects are native to the area or if they are invasive.

Soil

Soil can be affected positively and negatively by fire. The factors determining soil effects include soil moisture, the amount of organic matter present, and the intensity of the fire. The ideal fire for soil enrichment is a low intensity surface fire. Fires that burn too hot can cause soil destruction by making the soil hydrophobic and burning away minerals and organic matter in the soil.

Water

Fire can increase sediment runoff by removing the plants that kept soil in place. This can increase turbidity in streams and rivers. At Grand Canyon, heavy rains that immediately follow an intense fire can create runoff that flows down side canyons and into the river. In areas where burning occurs along the water’s edge, fire can increase the nutrient content of water by adding mineral-rich burned material.

Air

Smoke might be the most visible sign of fire- it can be seen looming even miles away on the horizon. Smoke affects air quality by increasing particulate matter (such as ash floating in the air). It can negatively impact human and animal breathing. It also decreases visibility. Fire planners at Grand Canyon National Park consider how smoke will affect visitors: Will it be too smoky to see into the canyon? Will people with respiratory issues not be able to enjoy their visit?

Activity: Fire and the Web of Life

Lesson Overview

Students will identify how species are interconnected by playing a game.

Lesson Objectives

Students will recognize how fire affects individual species and communities as a whole.

Materials

- Large index cards on string with ecosystem species
- About 8 pieces of string or yarn cut into 5 foot pieces **per student**

Activity Length

30 Minutes

Procedure

1. Start by brainstorming out loud plants and animals that live in a ponderosa pine forest. (Ponderosa is the easiest ecosystem to visualize when thinking about fire effects.)

2. Once students have come up with a good-sized list, pass out the index card necklaces to assign students a species. (The species cards should be similar to the brainstorming list.)

3. Once each student is assigned a species, students should observe the other assigned species and decide which ones they would be interconnected with in the wild. (For example, an Abert Squirrel is connected to ponderosa pines because it uses the tree for shelter and pinecones. Birds might be connected to flowers or trees, shade-tolerant flowers might be connected to tall pines, etc.) As long as the student can make a good argument for the connection, it should be valid- really, everything is connected!

Activity: Fire and the Web of Life

4. Move to an area where students can stand in a circle. Pass out the pieces of string to each student. Have students hold one end of their strings. Starting with any species, have that student say one other species she or he is connected to, and give the other end of one of their strings to the student wearing that species. Make sure the students explain the connection (i.e., is it for food? Shelter?) In cases where there is more than one representative of a species (i.e., there are three wildflowers) other students should connect to all representatives.

5. Continue going around the circle, with students naming who they are connected to and giving that species one side of their piece of string. Go around the circle until everyone is satisfied with their connections. It should look like a web in the center of the circle now, with people holding multiple ends of strings plus their own.

6. Now it is time for a fire to come through! As the students should know by now, fires can come as low intensity surface fires, or high-intesnity stand-replacement fires. You can have the students choose which they would like, or play with both. Once a wildfire comes through, ask students how their species has been affected by fire. Did they have to flee the flames? Were they burnt over by the fire? Did they have adaptations that helped them survive?

7. Once they have determined what happened to their own species, students must now determine how their fate has affected other species. For example, if a student was assigned to be a wildflower and a low-level ground fire came through, the student will have to drop their connections to whatever was dependent on the flower for food. Students should go around the circle deciding which connections can be kept and which should be dropped. Remember, this will depend greatly on the type of fire selected.

8. Now, fast-forward to a year later. What connections can be re-established? If a low-level fire came through, chances are grasses and flowers have begun re-appearing. If a high-intensity fire came through, maybe the soil has been so altered that nothing is growing back yet.

Discussion Questions:

a. Imagine you walk up to a forest that you know burned 12 months ago. How could you tell if the fire was a high-intensity one or a low intensity one?
b. How might flexibility help an animal survive in an area affected by fire?

Activity: Two Ecosystems on the Rim

Lesson Overview

Students will complete a contrast/compare chart to learn about Ponderosa pine forests and pinyon pine and Utah Juniper woodlands.

Lesson Objectives

Students will learn and identify differences and similarities between two common ecosystems of Grand Canyon South Rim.

Materials

- Journals and pencils
- Photo collages of Ponderosa Forests and Pinyon/Juniper Woodlands

Activity Length

30 Minutes

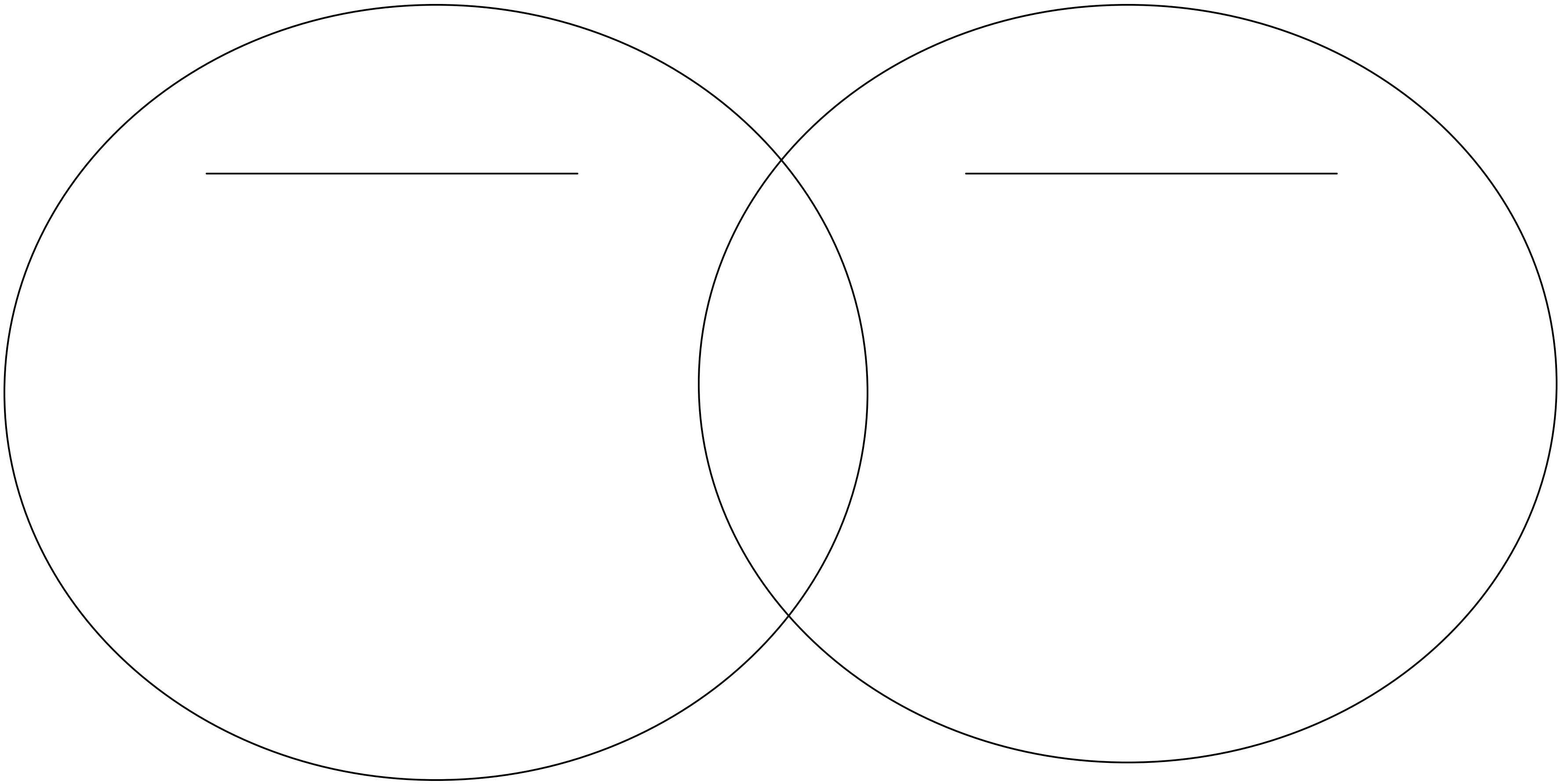
Procedure

1. Ideally, start this activity at the Shrine of the Ages or somewhere near the Rim Path. The goal is to walk through ponderosa pines and then pinyon/juniper woodland.

2. Starting in the Ponderosa forest, begin asking questions: What types of trees are these? What do you notice about them? Point out the lightning tree, and discuss briefly the fire adaptations of Ponderosas. Walk towards the rim and ask students to note the changes in vegetation. How does it look different? Is it sunnier or shadier here? What kinds of trees and plants are present now?

3. Complete the Comparison Chart for the two ecosystems.

Handout: Two Ecosystems Comparison Chart



Ponderosa Pine Forest Photographs

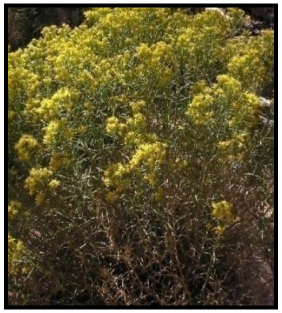
Ponderosa Pine (Pinus ponderosa)

Ponderosa Pine Forest Photographs

Plants

Creeping Barberry *(Mahonia repens)*

Mountain Muhly (*Muhlenbergia montana)*



Snakeweed (*Gutierrezia sarothrae*)

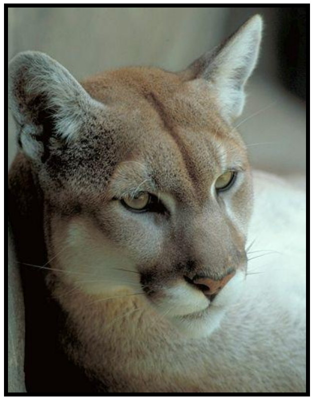
Lupine (*Lupinus hillii*)

Blue Grama (*Bouteloua gracilis*)

Ponderosa Pine Forest Photographs

Animals


Northern Flicker (*Colaptes auratus*)


Mountain Lion (*Puma concolor*)


Elk (*Cervus Canadensis*)


Abert Squirrel (*Sciurus aberti*)

Ponderosa Pine Forest Photograph Credits

Plants

Lupine
USDA Plant Database
http://plants.usda.gov/java/profile?symbol=LUHI2

Blue Grama
Wind Cave National Park
http://www.nps.gov/wica/naturescience/grasses-blue-grama.htm

Mountain Muhly
Forestry Images
http://www.forestryimages.org/images/768x512/1213032.jpg

Ponderosa pine forest
The Nature Conservancy
http://www.nature.org/wherewework/northamerica/lewisandclark/images/ponderosa_pine_oregon_charlie_ott.jpg

Snakeweed
USDA Plant Database
http://plants.usda.gov/java/profile?symbol=gusa2

Creeping Barberry
Lady Bird Johnson Wildflower Center
http://www.wildflower.org/gallery/result.php?id_image=21551

Animals

Abert Squirrel
Bandelier National Monument
http://www.nps.gov/band/naturescience/upload/abert's%20squirrel%20fact%20sheet.pdf

Northern Flicker
Utah Birds
http://www.utahbirds.org/birdsofutah/BirdsL-R_2/NorthernFlickerKK1.jpg

Elk
Arizona Game and Fish Department
http://www.azgfd.gov/h_f/highlights/images/ELK-004%20copy.jpg

Mountain Lion
Grand Canyon National Park
http://www.nps.gov/grca/naturescience/cynsk-v11.htm

Pinyon Pine and Utah Juniper Woodland Photographs

Pinyon Pine (*Pinus edulis*)

Utah Juniper (*Juniperus osteosperma*)

Pinyon Pine and Utah Juniper Woodland Photographs

Gambel Oak (*Quercus gambelii*)

Plants

Cliff Rose (*Purshia Mexicana*)

Pinyon Pine and Utah Juniper Woodland Photographs

Banana Yucca (*Yucca baccata*) Apache Plume (*Fallugia paradoxa*) Desert Paintbrush (*Castilleja angustifolia*)

Pinyon Jay (*Gymnorhinus cyanocephalus*)

Animals

Black-Tailed Jackrabbit (*Lepus californicus*)

Sonoran Gopher Snake

Mountain Short-Horned

Big Brown Bat (*Eptesicus fuscus*)

Pinyon Pine and Utah Juniper Woodland Photographs

(*Pituophis catenifer affinis*) (*Phrynosoma hernandesi*)

Plants

Pinyon Pine
Wikipedia
http://en.wikipedia.org/wiki/File:Juniperus_osteosperma_4.jpg

Utah Juniper
Northern Arizona Flora
http://www.nazflora.org/pinus_edulis.htm

Gambel Oak
Northern Arizona Flora
http://www.nazflora.org/Quercus_gambelii.htm

Banana Yucca
Northern Arizona Flora
http://www.nazflora.org/Yucca_baccata.htm

Cliff Rose
Lady Bird Johnson Wildflower Center
http://www.wildflower.org/gallery/result.php?id_image=22116

Apache Plume
Lady Bird Johnson Wildflower Center
http://www.wildflower.org/gallery/result.php?id_image=15699

Desert Paintbrush
Southwest Colorado Wildflowers, Ferns, and Trees
http://www.swcoloradowildflowers.com/Pink%20Enlarged%20Photo%20Pages/castilleja%20chromosa.htm

Animals

Pinyon Jay
NatureWorks: New Hampshire Public Television
http://www.nhptv.org/NATUREWORKS/pinyonjay.htm

Big Brown Bat
Western North Carolina Nature Center
http://www.wildwnc.org/education/animals/big-brown-bat-eptesicus-fuscus

Black-Tailed Jackrabbit
University of Michigan Museum of Zoology
http://animaldiversity.ummz.umich.edu/site/resources/phil_myers/ADW_mammals/Lagomorpha/lepus7003.jpg/view.html

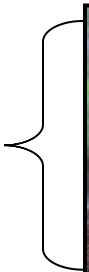
Sonoran Gopher Snake
City of Las Cruces Museum of Natural History
http://www.las-cruces.org/Public-Services/museums/nhm_nature_center_28_sonoran_gopher_snake.shtm

Mountain Short-Horned Lizard
Bryce Canyon National Park

Pinyon Pine and Utah Juniper Woodland Photograph Credits

http://www.nps.gov/brca/naturescience/shlizard.htm

Ponderosa Pine Adaptations



Ponderosa bark grows up to 4 inches thick.

Ponderosas shed their lower branches as they grow to keep their needles away from ground flames.

Thick Ponderosa bark protects the tree's living cambium.

Activity: Adaptation Derby

Lesson Overview

Students will create trees made of paper and light a low-level fire to test if the tree burns.

Lesson Objectives

Students will use their knowledge of Ponderosa pine adaptations to create a tree that will not burn under low-intensity fire conditions.

Materials

- Metal chemistry stand **per group**
- 5 chemistry stand clamps and rods **per group**
- Large newspaper cut into wide strips
- Intact newspaper
- Non-flammable pan **per group**
- Box of kitchen matches
- Rulers
- Hole punch **per group**
- Safety equipment (glasses, mitts, fire extinguisher)
- Journals

Activity Length

1 Hour

Procedure

WARNING: *This lesson requires igniting many matches under controlled conditions. Please conduct this lesson outside in a non-flammable area. Also, a* ***CLASS-A FIRE EXTINGUISHER*** *and* ***PROPER ADULT SUPERVISION*** *must be present during this lesson.*

This activity is set up as a competition between groups. Each group should aim to create a tree that will withstand a low intensity fire but which still maximizes the surface area of needles for photosynthesis. The competition will be in two phases: a qualifying round and a championship round.

Activity: Adaptation Derby

2. Arrange students into groups of no more than 4. Pass out materials. Each group should have: a chemistry stand with 5 rods, two handfuls of newspaper strips, two sheets of intact newspaper, a pan, and safety equipment.

3. Give students 10-15 minutes to construct their tree. To construct, students should punch holes in a strip of newspaper. These strips will then be threaded onto the chemistry stand rods. Students can put the newspaper strips onto the tree in any way they want to, but hole-punching gives the paper a means to stay on. The chemistry stand rods can be adjusted to any height desired. Remind students that the goal is to not catch the crown of the tree on fire while still maintaining enough needles to photosynthesize (i.e., there cannot be just one branch of needles at the very top of the tree, and needles on the tree cannot be very sparse).

4. After the trees have been constructed, have each group place their chemistry stand in their pan and layer two sheets of newspaper in the bottom of the pan (cutting a slit for the stand to come out of so that the newspaper lies flat).

5. Gather the class together to watch each group light their pan. Make sure everyone is wearing safety equipment. Each group will ignite the layers of newspaper on the bottom of the pan. Each group should ignite the paper in the same spot- the lower right hand corner is probably easiest.

6. Once the newspaper layers have burned to the other side of the pan the flames should put themselves out. Have the group measure the unburned sections of branches (wherever newspaper is left on the tree) and record the total (in inches) in their journal. The two groups who had the least-burnt trees now go to the championship round.

7. For the championship round, have the two top teams re-layer their pans with newspaper and place their tree (with no modifications) into the pan. All other groups become spectators for this round. Ignite the layers in the same place, one group at a time. Re-measure the length of unburned branch and compare. The group with the least-burnt tree is the winner!

Discussion questions:

- a. What made certain trees successful? Unsuccessful?
- b. Based on trees you've seen around Grand Canyon, do you think the trees that won had enough foliage to photosynthesize and live?
- c. What do you think would have happened if:
  - -We had put lots of curled and rolled up newspaper pieces on the bottom of the pan? We had put another tree right next to the first one?

Introduction

Field Experience Foreword

In this portion of the program, students will gather field data that will be used by Grand Canyon fire staff. This data will include tree counts and tree measurements, fuel counts, and information about plot location, among other information. Fire staff will use this data, along with their own, to better understand how fire effects Park landscapes.

Students will either sample or use example data from two different ecosystems: ponderosa pine forests and pinyon/ juniper woodlands. After data collection, students may have the opportunity to analyze this data.

The Field Experience will require the class or group to work well together. The general procedure is as follows:

1) Students will navigate to the plot as a whole group.

2) With the help of the facilitator, the whole group will set up the plot by placing plot markers on location and taking data about the topography.

3) Students will split into their assigned smaller groups and complete the specific group protocols.

4) Students will reconvene and discuss the experience.

Activity: Geocaching for Treasure

Lesson Overview

Students will use GPS devices to search for hidden "treasure."

Lesson Objectives

Students will learn to use a GPS device and interpret the information given by the device.

Materials

- GPS device **per group**
- One small box **per group** filled with tiny "treasures" such as bookmarks, pens, stickers, etc. (enough treasures so that everyone in the group gets something!)

Activity Length

1 Hour

Procedure

1. Before class, hide the small boxes in a close-by area. They should not be buried, but rather semi-concealed. They should be within reach of the students.

2. Plot each group's hiding spot onto their GPS unit (so that two groups aren't navigating towards the same box).

3. During class, go over GPS procedures. Explain what GPS is and what it can do. Refer to *How To Use the Magellan Triton 200*.

4. Divide the students into groups of no more than 6. Give each group a GPS device.

5. Go outside as a class and have each group locate its hidden treasure! Each group should be able to report to the class at what latitude and longitude the treasure was located.

Overview of Protocols

Below is a general description of each protocol group's responsibilities. More detailed descriptions follow Plot Set-Up.

Photo Points

Photo points are an important tool to visually document how landscapes change over time. Students will photograph the plot following the Photo Point Protocol. Students need to remember to take care of the camera by using it only to take photos of the plot and putting the camera in its case after every shot. Students will need to discuss a way of notifying other groups to hide when the photos will be taken. Examples might be to yell "Cougar!" to have students hide and then "Squirrel!" for students to come out of hiding.

A common question is: Why can't we have students in the picture? The answer, in short, is because we are here to study the resource. A student may cover a key piece of information that might be needed in the future.

Plot Location

Knowing the location of a plot is valuable if the plot needs to be revisited. It is also helpful to know physical characteristics of the plot, such as slope and aspect, to understand how fire and other natural phenomena will act on the landscape.

Note: The photo points group can join this group to extend the time of their group's participation.

Measuring Dead and Downed Fuels

Fire fuels are one of the major contributors to wildland fire. Students will learn about different types of dead downed fuels and how to measure them.

Note: If this is a large group or students want more experience have another group complete Transect 2. This transect is optional.

Monitoring Trees

Trees ecosystems are an integral part of the park. Both plants and animals depend greatly on trees for food and shelter. The composition of forests is also a major factor in what effect a fire might have in that area. Denser forest canopies may allow fire to move from one tree to another causing a more intense and destructive fire. A spaced canopy may prevent a fire from jumping from one tree to another. Younger, smaller trees or pole trees might act as a ladder for fire to get into the forest canopy. Students will collect data that will be used to determine the composition of the forest canopy.

Overview of Protocols

Shrubs and Herbaceous Plants

Shrubs and herbs can influence fire behavior at the ground level. These two fuels can also act as a ladder to move fire from the ground up to smaller trees and then into the canopy. Both shrubs and herbaceous strata are measured to quantify the amount of ground cover. Students will collect data to determine the amount of coverage. In addition, students will learn about invasive plants and determine if any are present in the sample area.

Protocol Group	Recommended Number of Students in Group
Photo Points	2
Plot Location	2
Measuring Dead and Downed Fuel Load	2-4
Monitoring Trees	2-5
5. Shrubs and Herbaceous Plants	2-3

Plot Set-Up

Materials

- Mallet
- Three Pre-tagged markers (OP, 50P, 50PB)
- Compass
- GPS
- Clinometer
- Two 50m Metric/English tapes
- Two 15m Metric/English tapes
- Two Tree Go-No-Go
- Fire Fuels Go-No-Go
- Plot board w/ dry erase marker
- Digital camera
- Map

Plot Set-up (Everyone)

1. Split into Protocol groups and distribute Protocol packets and sumarize basic overview listed below for each group. Note: This would be a good time to for the Photo Points group to discuss a way to notify everyone whether or not a picture is being taken.

2. The Plot Location Group should navigate the group to the plot. Once the group is within 5 meters of the plot location, refer to "Rejection Criteria" below. Discuss whether or not the site is representative of the assigned monitoring type (i.e. ponderosa forest or pinyon/juniper woodland), and whether any rejection criteria are met. Note: Site will be pre-visited by facilitator so no rejection criteria should be met.

3. Once the group is within 5 meters of the plot location, have a student use the mallet to hammer in the marker tagged with 0P. Since Grand Canyon soil is extremely rocky, feel free to move the 0P marker until it is able to be pounded at least 4 inches into the ground without hitting obstructions.

4. Have a student stand over the 0P marker and start spinning the compass dial. Assign another student to say "**STOP!**" after a few moments of spinning. DO NOT move the dial anymore. The student who is holding the compass should then turn so that the red needle is inside the orienting arrow ("The red is in

Plot Set-Up

5. the shed”). Refer "Parts of a Compass". Make sure this student is standing behind the 0P marker facing the direction that the peep sight is pointing continuing to keep the red needle inside the orienting arrow. The number in line with the white notch will be the *azimuth* for Transect 1.

6. Have another student attach one end of the 50m Metric/English tape to the 0P mark. Using the compass, have another student direct the student holding the tape to walk along the Transect 1 *azimuth* for 50 feet. At 50 feet, another student should pound in the 50P marker. Continue to run the tape another 50 feet along the same *azimuth*. Lay the tape reel down when a total of 100 feet is reached for Transect 1. See "Student Rapid Assessment Plot".

7. **Optional - If this is a large group or students want more experience have another group complete Transect 2. This transect is not necessary.** At the 0P marker, use the compass to make another transect that is 90 degrees to the right (clockwise) from Transect 1. This will be Transect 2. Example: If Transect 1 had an *azimuth* of 110 degrees, Transect 2 will have an *azimuth* of 200 degrees.

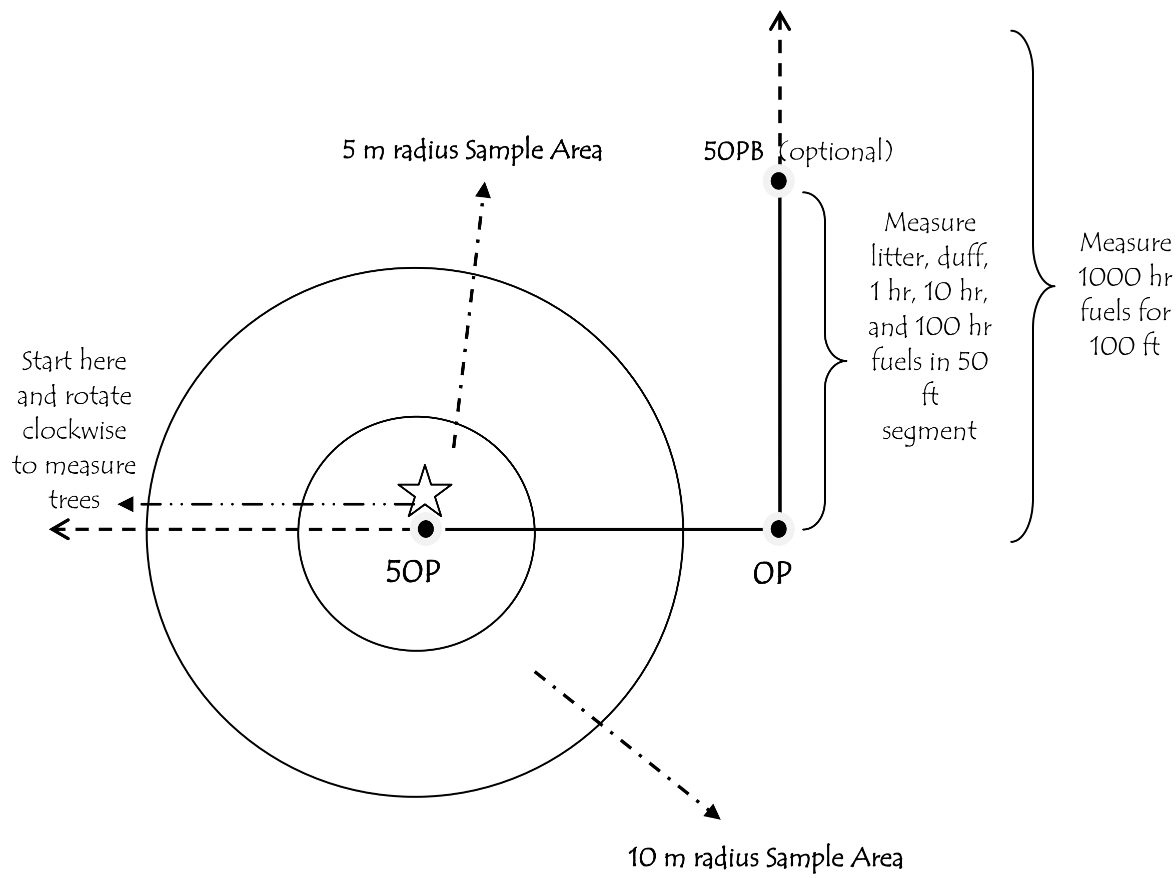
8. Repeat step 5: pound in the 50PB marker at 50 feet. Continue to run the tape another 50 feet along the same *azimuth*. Lay the tape reel down when a total of 100 feet is reached for Transect 1. See diagram

Rejection Criteria

Look at the chosen site. Do any of these apply?

- Do large rock outcroppings cover more than 20% of the *plot area*?
- Is the area within 50 meters of roads/utility corridors/trails/fuel breaks/slash piles?
- Is the area within 50 meters of significant prehistoric/historic sites or transitional *ecotones*?

Student Rapid Assessment Plot (SRAP) Diagram



0P = point zero (start of the plot)
50P = 50 feet away from point zero along Transect 1
50PB = 50 feet away from point zero along Transect 2

Introduction

Activity: Skills Round Robin

Lesson Overview

Students will rotate through learning stations to learn how to use plot work tools.

Lesson Objectives

Students will learn to use the tools needed for plot work.

Materials

- Compasses
- GPS units
- Tape Measures: 50 meter English-Metric, 15 meter English-Metric
- Clinometer(s)
- Fuel Go-No-Go(s)
- Tree Go-No-Go(s)
- Rulers and yardsticks

Activity Length

1 Hour

Procedure

Before the lesson, set up the following stations:

1. Litter and Duff Station- **Litter and Duff Photograph** (found in Monitoring Dead and Downed Fuels protocol), rulers, litter-duff-soil example vial
2. Go-No-Go Station- Tree Go-No-Go's and description, Fuel Go-No-Go's and description
3. Compass and GPS Station- multiple compasses and GPS units, **Parts of a Compass Photograph** (found in Plot Location protocol)

Activity: Skills Round Robin

4. Tape Measure and Clinometer Station- multiple clinometers - one each of 50 meter tapes and 15 meter tapes, and **Brown's Transect Photograph** (found in Monitoring Dead and Downed Fuels protocol).

1. Arrange students into groups of no more than 5.

2. Pass out a copy of each worksheet to every student. They can be stapled into a packet- students will carry them to each station.

3. Set up a rotation schedule so that each group goes to every station. Students should be at the station for 8-10 minutes. Switch stations after this period of time.

4. After all groups have visited each station, reconvene and go over the worksheet answers and any questions students might have.

Station 1: Litter and Duff Worksheet

1. Use the ruler to measure the amount of litter in the vial. ___________

2. Use the ruler to measure the amount of duff in the vial. ____________

3. Circle everything that is considered litter:

Pine Needle Pine Cone Leaf Twig Decomposed Pine Needles

4. What units are litter and duff measured in?

Station 2: Go-No-Go Worksheet

1. Looking at the Tree Go-No-Go, what Class would a 8 centimeter tree fit into? __________

2. Looking at the Fuel Go-No-Go, what Class would a 1.5 inch fuel fit into? ___________

3. Circle everything that should be measured with a Fuel Go-No-Go:

Pine Cone Pine Needle Twig Log Stump Fallen Branch

4. True or False: When using a Go-No-Go, check if the fuel or tree fits into the smallest notch first.

Station 3: Compass and GPS Worksheet

1. Looking at the compass, which direction is both 0º and 360º?

2. Write the steps to Mark a Waypoint in the GPS.

3. Write the declination of your compass.

4. From how many satellites is the GPS receiving signals?

Station 4: Tape Measure and Clinometer Worksheet

1. Using the tape measure, measure the height of the person next to you in meters:_______
In feet:_______

2. Measure 1.37 meters out on the tape measure. How many feet is 1.37 meters equivalent to?

3. Looking into the clinometer, which side tells you percent slope? Left Right

4. Working with the person next to you, measure the percent slope of each others' eye level.

Yours:_______ Your partner's:______

5. Using the percent slopes from #4, who is taller? ______________
How can you tell?

Handout: Making Predictions about Field Data

Fire staff at Grand Canyon National Park use data to answer questions about the Park environment. Fire staff follow a process often referred to as the scientific method to help them understand what certain data means (see the attached chart for an overview of the scientific method).

After collecting data, you too will have a chance to analyze the findings and answer a specific question. Use this handout to brainstorm a question you want investigate, and predict the answer to that question based on what you have learned so far.

Observations

Take a moment to think about what you have learned so far in this program. You will be using this information to make predictions about the data your class will collect in the field.

Questions

Now that you know what data your class will collect, take a moment to think about what you might find out from that data. What questions do you have about fire ecology and forests that might be answered by this data? For example, you might wonder if your class will find a greater number of logs on the ground in an area with more large trees.

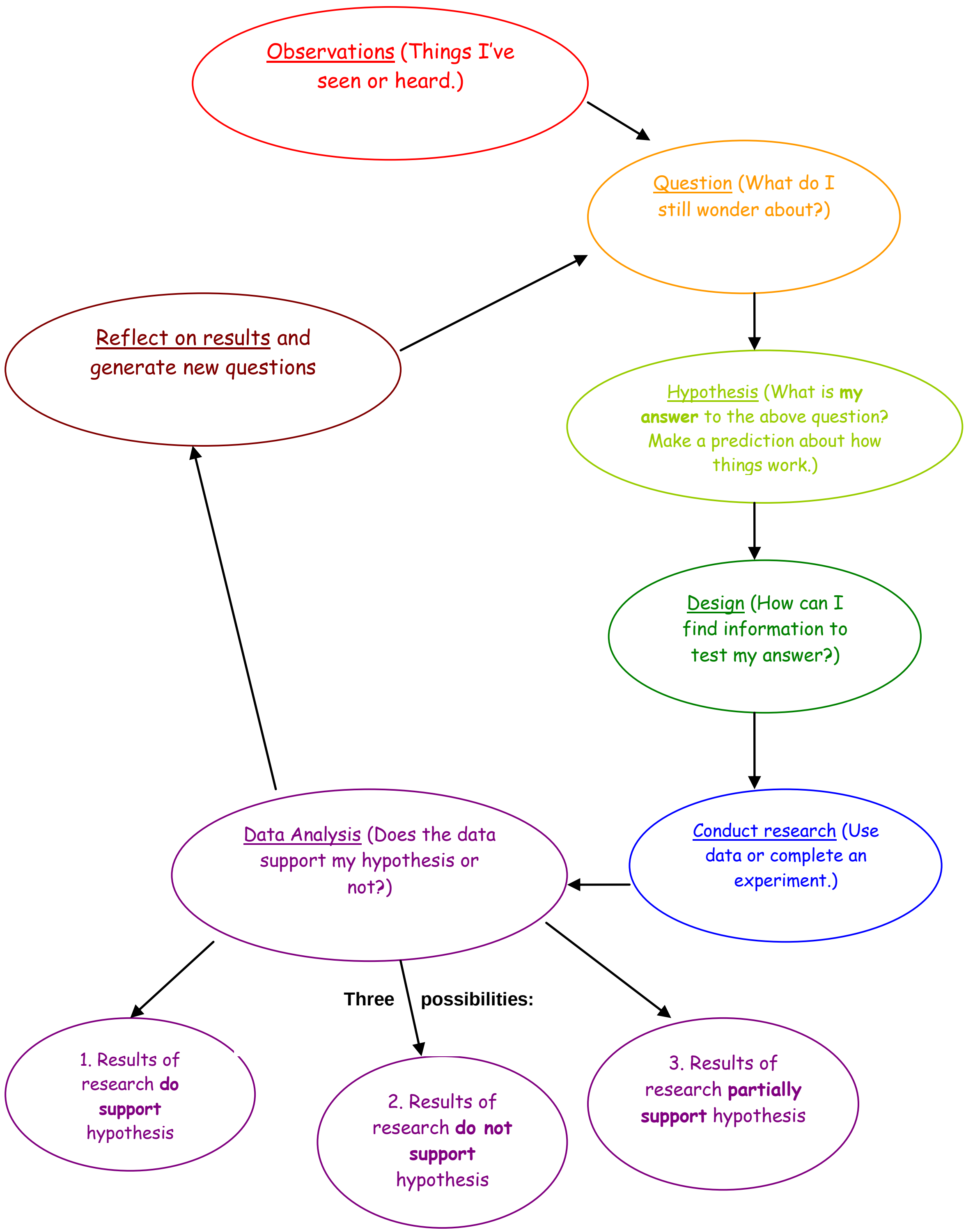
Write your question(s) here:

Predictions

Predict the answers to your questions. For example, if one of your questions was: <u>Do forests with more large trees have more fuels on the ground?</u> your predicted answer might be <u>Forest areas with larger trees have more fuels on the ground.</u>

Write your predictions here:

Handout: Making Predictions about Field Data



Field Protocols

Photo Points

Background
Documenting plots with photo points helps us study how a landscape changes over time.

Equipment
- Plot board with dry erase marker
- Digital camera with case
- Tape measure

Procedure
1. Read through the whole procedure once before starting the procedure. Ask questions for clarification if necessary.

2. Designate one photographer and one photographer's assistant.

3. Have the photographer's assistant label the attached RAP (Rapid Assessment Plot) Plot Boards using the dry erase marker with the appropriate PLOT ID, STATUS and DATE. Note: All information can be found on the SRAP 1 Plot Location Data Sheet. Ask the Plot Location Group for this information.

4. Make sure that the plot photo board is labeled correctly before moving onto the next step.

5. Place the photo plot board so that it is leaning right side up on the 0P stake. See **Perfect Picture** photograph below.

6. The photographer should take roughly two strides back from the plot stake. The photographer's assistant needs to make sure the following image criteria are met by checking the conditions or asking the photographer:
   - The camera is being held four feet above ground.
   - The image is level with the bottom of the photo plot board.
   - The image is centered on the plot tape.
   - No people are in the picture. Yelling politely may be necessary- this is important!

7. Take the picture when all conditions are met.

8. Both the photographer and photographer's assistant should review the photograph to make sure all of the above conditions are met.

Photo Points

9. Once the photo has been checked, the photographer and assistant should switch roles.

10. Repeat Steps 2-8 until the four required plot photos are complete. Follow the sequence listed in the table below. **Remember- Transect 2 is optional, check if you are completing the transect with the facilitator.**

Sequence of plot photos:

Subject	Photo Point Code
1. From 0P stake toward 50P stake	0P-50P
2. From 50P stake toward 0P stake	50P-0P
3. (Optional) From 0P stake toward 50PB stake	0P-50PB
4. (Optional) From 50PB stake toward 0P stake	50PB-0P

Perfect Picture

50P→0P

PLOT ID
STATUS
DATE

0P→50P

PLOT ID
STATUS
DATE

50PB→0P

PLOT ID
STATUS
DATE

0P→50PB

PLOT ID

STATUS

DATE

Plot Location

Background

Knowing the location of a plot is valuable if the plot needs to be revisited. The physical characteristics of a plot, such as slope and aspect, also help fire managers know how fire will affect a certain landscape.

Equipment

- Clinometer
- GPS
- Map of general plot location
- Tape measure
- Compass

Procedure

1. Read the plot background sheet.

2. Fill in the appropriate information on the data sheet based on the background information.

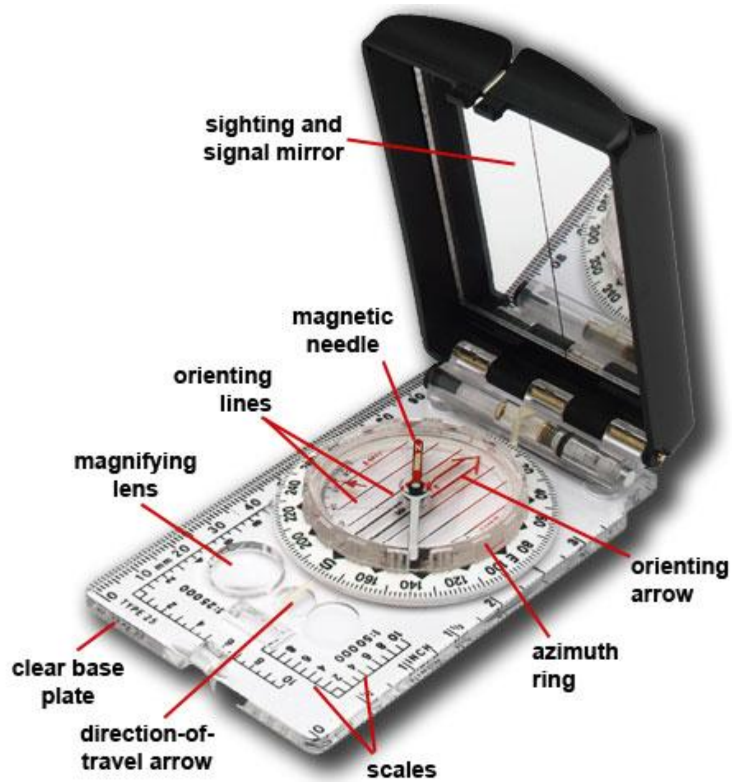
3. Write the name of your school or group on the data sheet next to Group Name.

4. Access the point within the GPS unit and record the UTM's at the marked point. Note: UTMe contains six digits while UTMn contains seven digits.

5. Determine the aspect of the plot using the compass. To do this, stand near the 0P marker. Imagine pouring a bucket of water on the ground. Which way would it flow? Face the direction it would flow. While facing the direction the imaginary water would flow, turn the dial of the compass until the red needle is inside the orienting arrow ("The red is in the shed.") Read the direction of the aspect by looking at the Peep Sight above the dial. Which of these is the Peep Sight in line with?

   North, NE, NW, South, SW, SE, West, or East

Plot Location



Record the aspect on the data sheet. Use the GPS unit to record the elevation of the plot point in meters.

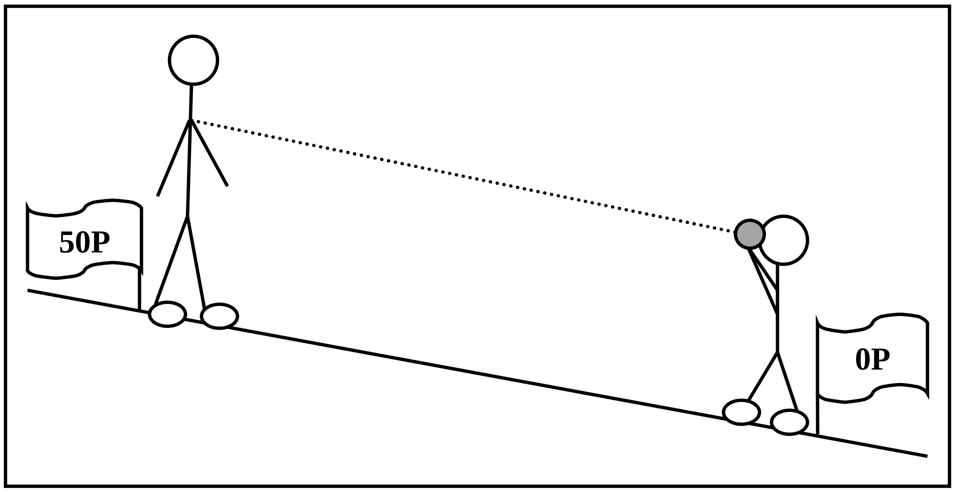
6. Use the tape measure to determine the height of eye level for each student. Jot down the height of the shorter student to remember it.

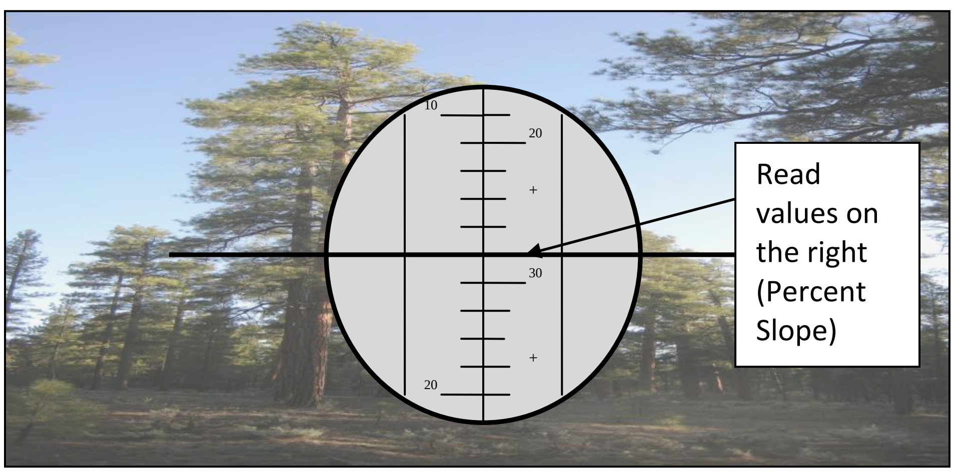
7. Measure that height you wrote down on the taller student. For example, if eye level for the shorter partner was 4’3”, measure from the taller partner’s feet up to 4’3”- this could be chin or neck height on the taller partner. Remember where the shorter partner’s eye height falls on the taller partner.

8. Have the shorter partner stand at 0P with the clinometer while the taller partner stands at 50P. Hold the clinometer, dial facing your left, to your right eye while keeping both eyes open. Match up the line in the clinometer to the height you just found on the taller student in step 7.

Plot Location

9. Read and record the percent slope for both Transect 1 and also Transect 2 (repeat step 8 except taller partner stands at 50PB marker- Remember, you might not be reading Transect 2 since it is optional). Make sure you are reading percent slope (right number) and not degrees.





10. Using at the map and the GPS unit, write directions to get to the plot on the data sheet.

11. Draw a map of the plot and its general area, including major features such as roads, trails, natural features, etc. Mark on the map how to get to the plot. Note: You can use the GPS unit to give you an idea of how far apart things are by using the scale on the screen.

Plot Location

12. Make sure you include STAND on your map: Scale, Title, Author, North Arrow, and Date.

SRAP-1 PLOT LOCATION DATA SHEET- EXAMPLE

Plot ID __PIPO41_ Rx / Thin / Unknown (circle one) Date 10/10/10
Treatment Unit BUGGELN Treatment Status: PRE POST ____
Vegetation Type ___ponderosa pine OR pinyon/juniper_______________
GroupNames_______Mary, Joe, Jennifer, Steve
From GPS screen:
UTM Zone 12 N UTMe 0415087 UTMn 3981980

Aspect North (cardinal direction) Elevation 2191 meters

Slope (*from OP➔50P*) 10%
Transect Azimuth (*from OP➔50P*) 15%
(Optional) Slope (*from OP➔50PB*) 10%
Transect Azimuth (*from OP➔50PB*) 10%__

Treatment History of the Plot:
This plot had a low-intensity fire in 1999.

Did you deviate from the protocols? If yes, describe:

VERY SPECIFIC DIRECTIONS TO PLOT (WHERE EXACTLY IS OP?)

Starting at the Village Loop Rd. we walked 100 ft North. Then we turned West and walked 100 ft. We passed a very large ponderosa with a big lightening scar from the bottom to the top. The plot location was about 20 ft after this ponderosa.

(Draw a map here. Remember: STAND- Scale, Title, Author, North Arrow, Date)

Did you remember:

- ❑ Which road/trails(s) to drive/walk on and rough mileages to get to the plot?
- ❑ Did you get GPS coordinates for the plot
- ❑ Does your map **STAND** (Scale, Title, Author, North Arrow, Date)?

Measuring Dead and Downed Fuel Load

Background

Fuel loads are measured using the English System (inches, feet, etc.), whereas all other measurements on the plot are measured using the Metric System (centimeters, meters, etc.).

For this protocol, you will focus on dead fuels. Dead fuels no longer gain moisture through their root systems and do not have living tissues. These fuels can absorb water like a sponge from their surroundings from sources such as precipitation, snow melt, etc. Dead fuels are classified into categories based on not only their physical characteristics but also on their ability to lose water. A good rule of thumb is the smaller the fuel the quicker the fuel will lose moisture. This loss of moisture leads to a greater susceptibility to fire during the drier months of the year. The chart below explains what fuel types you will be looking at while reading this transect.

Procedure

Note: Make sure to limit disturbance to the transect by keeping a two foot walking buffer on either side of the tape. This buffer can only be broken by the measurer when taking measurements. When measuring fuels do not pick up or move the fuel being sampled.

1. Read through the whole procedure once before starting the procedure. Ask questions for clarification if necessary.

2. Designate a recorder and a measurer.

3. Review **Fuel Go-No-Go** below.

4. Start at the 0P mark. Your group will first read Downed Woody Debris <u>1 hour, 10 hours, and 100 hours fuels</u> along the transect from 0P→6 ft. Move along the transect line from 0P→6 ft. When the measurer encounters a fuel, use the Go-No-Go to determine diameter and report the fuel to the recorder.

5. On the data sheet, the recorder should tally all fuels that cross the transect line. The fuels must also be under six feet off the ground. Most fuels will be under the tape measure line, but a downed tree with branches might also cross the line above the tape measure leaving some fuels to be counted below six feet.

   → Fuels are measured at the point where the fuel's central axis intersects the transect line. Remember, in order to be tallied, the fuel must completely cross the transect line

Measuring Dead and Downed Fuel Load

either above or below the tape measure. Refer to the **Transect Photograph** below for help.

6. Once the measurer reaches the 6 ft mark, he or she should continue to tally the number of 100 hour fuels that cross the transect line between the 6 ft mark and the 12 ft mark. *Do not tally any more 1 hour or 10 hour fuels after the 6 ft mark.*

7. Go back to the 0P marker. Using the ruler, move down the transect and decide whether each log you encounter is **Sound** (S) or **Rotten** (R). End at the 100 ft mark.

   Sound logs are intact and solid but may have no bark.
   Rotten logs are decomposing and broken apart.

   Measure the diameters of any logs larger than 3 inches that cross the transect line. Round your answer to the nearest half inch. Record the log's diameter in the correct column. (i.e., if the log is rotten and 4 inches in diameter, record 4.0" in the Rotten column, not the Sound column.)

8. Go back to the 0P marker. Measure and record litter and duff every 5 ft, starting at 1 ft and continuing with 5 ft, 10 ft, 15 ft, etc. End at the 45 ft mark. (Don't start right at the 0P marker because it has been trampled and may have been altered during the plot set-up phase.)

   To measure litter and duff, insert the metal ruler into the ground at the measurement point and create a small hole. **Only measure litter and duff: don't stick the ruler into mineral soil. There may not be a large duff layer where you sample.** Use the descriptions below to decide where the layers are located. Refer to the sample photograph for help. Round this data to the first decimal place.

   Switch roles and start at the 0P marker. Repeat the above steps for Transect 2 (0P→50PB). **Remember- Transect 2 is optional, check if you should complete the transect with your facilitator.**

Measuring Dead and Downed Fuel Load

Fuel Categories/Measurement Location

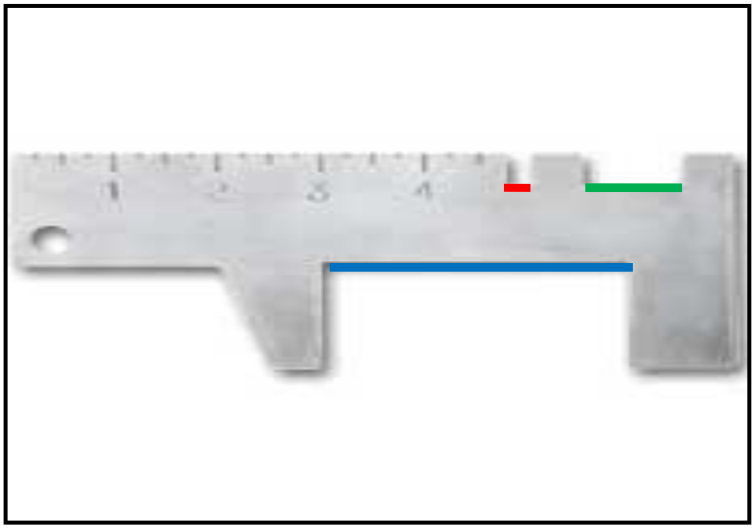
Fuel Category	Size	Description	Sample Length
Litter	Variable	Top separated layer including leaves, needles, bark flakes, cone scales, cones, acorns, dead unattached grass. Plant structures are still discernable and have little to no alteration by decomposition.	Measure every 5 ft starting at 1 ft mark and ending at 45 ft mark.
Duff	Variable	Fibrous, consolidated, decomposed layer above mineral soil. Usually rare on the S. Rim.	Measure every 5 ft starting at 1 ft mark and ending at 45 ft mark.
Downed Woody Debris	0-0.25 in. diameter (1 hour category)	Dead woody twigs or branches that require 1 hour to dry.	Tally all that are present between 0 ft and 6 ft.
	0.25-1 in. diameter (10 hour category)	Dead woody twigs or branches that require 10 hours to dry.	Tally all that are present between 0 ft and 6 ft.
	1-3 in. diameter (100 hour category)	Dead woody twigs or branches that require 100 hours to dry.	Tally all that are present between 0 ft and 12 ft.
	3 in.< diameter (1000 hour category)	Dead branches or logs that require 1000 hours to dry. Classified as either **Sound** (S) (logs are solid) or **Rotten** (R) (logs are breaking apart).	Measure every log along transect from 0-50 ft.

Fuel Go-No-Go

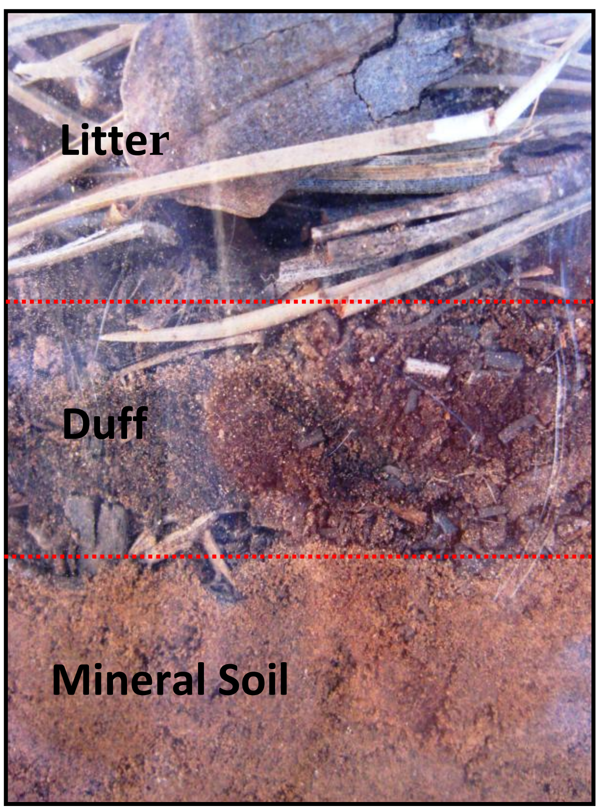
A Go-No-Go gauge is a tool used to separate items into size classes. In this case, the Go-No-Go is used to separate Downed Woody Debris into categories based on diameter. The Go-No-Go has three notches that correspond to the three fuel sizes. The smallest notch (0.25 in wide) corresponds to **1 hour fuels**, the middle sized notch (1 in wide) corresponds to **10 hour fuels**, and the largest notch (3 in wide) corresponds to **100 hour fuels**.

To determine what class Downed Woody Debris should be tallied under, start with the smallest notch. If the fuel's diameter is too large to fit into the notch, move to the next largest notch. It is very important to start at the smallest notch and move towards the largest notch, not the other way around. The notch the Downed Woody Debris fits into correlates to the fuel's diameter category.

For example, if your group found a twig that crosses Transect 1 the Go-No-Go should be used to determine the fuel class. If the twig's diameter does not fit in the smallest notch but does fit in the middle notch, the twig would be tallied under the 10 hour fuel type.

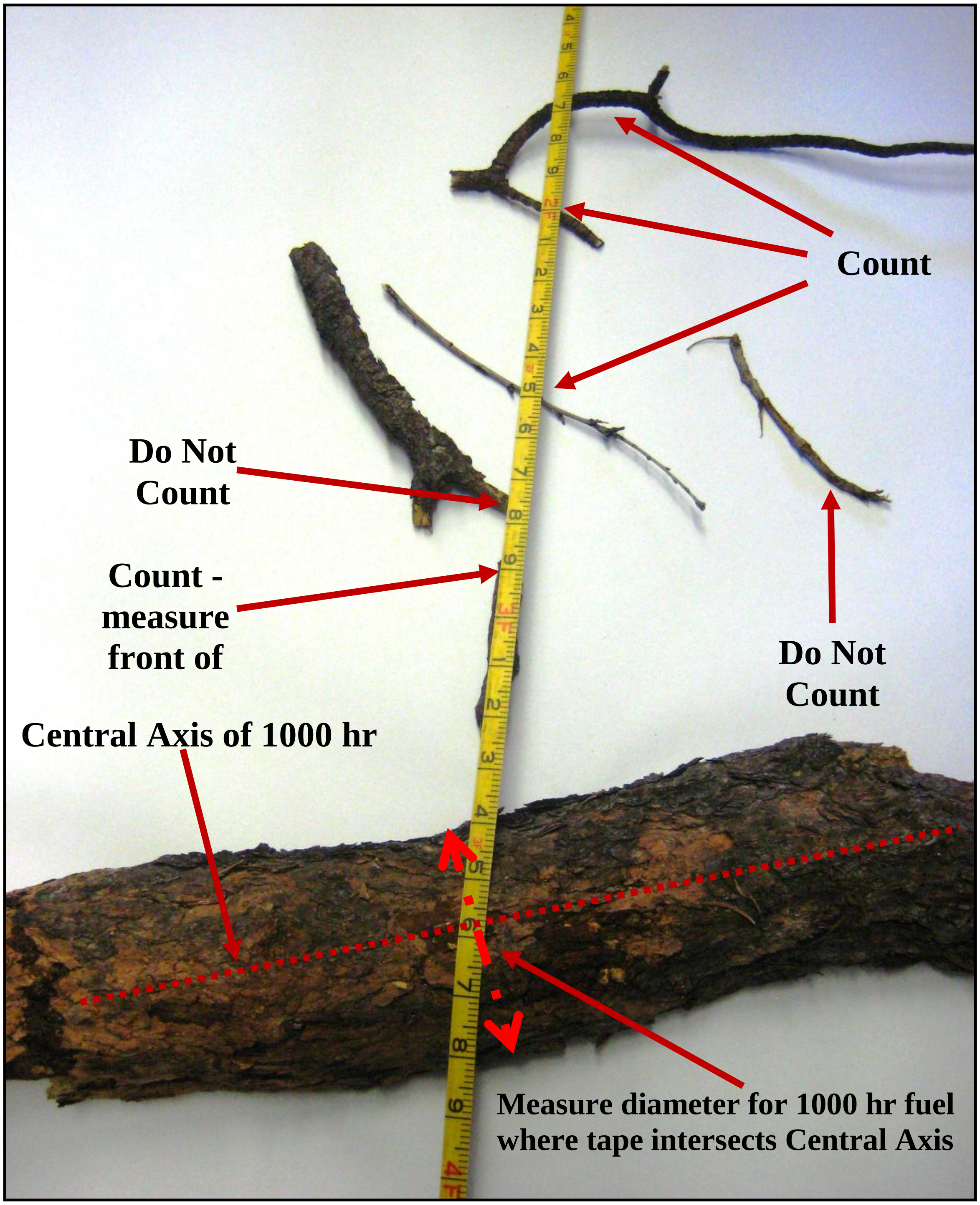


Forest Floor Sample Layers



Measuring Dead and Downed Fuel Load

Transect Photograph



SRAP-4 DEAD & DOWNED FUEL LOAD DATA SHEET- PONDEROSA EXAMPLE

Plot ID PiPo41 Rx / Thin / Unknown (circle one) Date 10/10/10

Treatment Unit BUGGELN Recorders Jennifer, Steve, Mary

Treatment Status: PRE POST ____

Reminders: 1) hr = hour 2) If a tree, stump, or rock is encountered enter 0 litter, 0 duff.	1hr that are 0 –¼″ & under 6′ tall	10hr that are ¼″ –1″ & under 6′ tall	100hr that are 1″ – 3″	1000hr that are Sound 3″ or bigger dia. to nearest 0.5″ Record diameter=		1000hr that are Rotten 3″ or bigger dia. to nearest 0.5″ Record diameter=		Litter and Duff Depths, nearest 0.1″					
								Sample Location	Litter (ex: pollen cones, pine cones, needles)	Duff (partially decomposed)	Sample Location	Litter (ex: pollen cones, pine cones, needles)	Duff (partially decomposed)
Tally Fuels Transect 1 OP-50P	III	IIII II	I	**3.5**		**3.0**		1′	1.0	0	25′	**0.2**	**0**
				4.0		**4.5**		5′	0.3	0	30′	**0.1**	**0**
				4.0		**4.0**		10′	0.5	0.3	35′	**0**	**0**
				4.5		**4.0**		15′	0.5	0	40′	**0.3**	**0.4**
Totals	**Total 3**	**Total 6**	**Total 1**					20′	0.2	0	45′	**0**	**0**

Tally Fuels Transect 2 OP-50PB Did you complete? Y or N								1′			25′		
								5′			30′		
								10′			35′		
								15′			40′		
Total	**Total**	**Total**	**Total**					20′			45′		

Fuel Type	Size	Description	Sample Length
Litter	Variable	Top separated layer including leaves, needles, bark flakes, cone scales, cones, acorns, dead unattached grass. Plant structures are still discernable and have little to no alteration by decomposition.	Measure every 5 ft starting at 1 ft mark and ending at 45 ft mark.
Duff	Variable	Fibrous, consolidated, decomposed layer above mineral soil. Usually rare on the S. Rim.	Measure every 5 ft starting at 1 ft mark and ending at 45 ft mark.
Downed Woody Debris	0-0.25 in. diameter (1 hour)	Dead woody twigs or branches that require 1 hour to dry.	Tally all that are present between 0 ft and 6 ft.
	0.25-1 in. diameter (10 hour)	Dead woody twigs or branches that require 10 hours to dry.	Tally all that are present between 0 ft and 6 ft.
	1-3 in. diameter (100 hour)	Dead woody twigs or branches that require 100 hours to dry.	Tally all that are present between 0 ft and 12 ft.
	3 in.< diameter (1000 hour)	Dead branches or logs that require 1000 hours to dry. Classified as either **Sound** (S) (logs are solid) or **Rotten** (R) (logs are breaking apart).	Measure every log along transect from 0-50 ft.

SRAP-4

DEAD & DOWNED FUEL LOAD DATA SHEET- PINYON/JUNIPER EXAMPLE

Plot ID PIED 13 Rx / Thin / Unknown (circle one) Date 10/10/10

Treatment Unit SHOSHONE Recorders Steve, Mary, Jennifer

Treatment Status: PRE POST 1 year later

Reminders: 1) hr = hour 2) If a tree, stump, or rock is encountered enter 0 litter, 0 duff.	1hr that are 0 –1/4″ & under 6′ tall	10hr that are 1/4″ –1″ & under 6′ tall	100hr that are 1″ – 3″	1000hr that are Sound 3″or bigger dia. to nearest 0.5″ Record diameter=		1000hr that are Rotten 3″ or bigger dia. to nearest 0.5″ Record diameter=		Litter and Duff Depths, nearest 0.1″					
								Sample Location	Litter (ex: pollen cones, pine cones, needles)	Duff (partially decomposed)	Sample Location	Litter (ex: pollen cones, pine cones, needles)	Duff (partially decomposed)
Tally Fuels Transect 1 OP-50P	I	I	II	3.0		5.5		1′	0.3	0	25′	0.2	0
						4.0		5′	0.2	0	30′	0.2	0
								10′	0.2	0	35′	0.3	0
								15′	0.3	0	40′	0.2	0
Total	Total 1	Total 1	Total 2					20′	0.1	0	45′	0.4	0.1

Tally Fuels <u>Transect 2</u> <u>OP-50PB</u> Did you complete? Y or N								1′			25′		
								5′			30′		
								10′			35′		
								15′			40′		
Total								20′			45′		

Fuel Type	Size	Description	Sample Length
Litter	Variable	Top separated layer including leaves, needles, bark flakes, cone scales, cones, acorns, dead unattached grass. Plant structures are still discernable and have little to no alteration by decomposition.	Measure every 5 ft starting at 1 ft mark and ending at 45 ft mark.
Duff	Variable	Fibrous, consolidated, decomposed layer above mineral soil. Usually rare on the S. Rim.	Measure every 5 ft starting at 1 ft mark and ending at 45 ft mark.
Downed Woody Debris	0-0.25 in. diameter (1 hour)	Dead woody twigs or branches that require 1 hour to dry.	Tally all that are present between 0 ft and 6 ft.
	0.25-1 in. diameter (10 hour)	Dead woody twigs or branches that require 10 hours to dry.	Tally all that are present between 0 ft and 6 ft.
	1-3 in. diameter (100 hour)	Dead woody twigs or branches that require 100 hours to dry.	Tally all that are present between 0 ft and 12 ft.
	3 in.< diameter (1000 hour)	Dead branches or logs that require 1000 hours to dry. Classified as either **Sound** (S) (logs are solid) or **Rotten** (R) (logs are breaking apart).	Measure every log along transect from 0-50 ft.

Monitoring Trees

Fire managers are concerned with trees of a specific size because of the role those trees can play in an *ecosystem*. For example, Northern Goshawks at Grand Canyon National Park prefer larger diameter trees for nesting.[1] Fire managers might be concerned with not killing larger trees in order to preserve Northern Goshawk habitat. By measuring the presence or absence of different size trees before and after a fire, we can understand how fire affects *forest composition*.

In this protocol, you will measure four classes of trees at different stages of their lives. Tree life stage often correlates with tree trunk thickness (diameter). For example, seedlings are often Class I trees, while large, old-growth trees fall under Class IV trees.

There are four common species of trees found on the South Rim of the Grand Canyon: ponderosa pine, pinyon pine, gambel oak, and Utah juniper. For all four species, diameter is measured in centimeters. In this exercise, a Go-No-Go tool will be used to categorize trees into Diameter Classes. Also, height and species data will be recorded. Trees will be sampled within a *fixed radius plot*.

[1] Crocker-Bedford, Cole (2003). *Habitat Effects on Northern Goshawks*. Literature Review, Tongass National Forest, Alaska.

Monitoring Trees

Classification of Tree Life Forms for Student Rapid Assessment Plots

Diameter Class	Description: Ponderosa pine, Pinyon pine, Gambel oak	Description: Utah juniper	Sample Area	Other Measure-ments
I	Standing tree, living, with a diameter < 2.5 cm at *diameter breast height*. (Trees with less than 2.5 cm diameters might not have a *diameter breast height* because they are under 1.37 meters tall.)	Standing tree, living, with a diameter < 2.5 cm at *diameter at root crown.*	**5 meter radius** around 50P marker	Height Class
II	Standing tree, living, with a diameter ≥ 2.5 cm and ≤ 15 cm at *diameter breast height*.	Standing tree, living, with a diameter ≥ 2.5 cm and ≤ 15 cm at *diameter at root crown*.	**10 meter radius** around 50P marker	Height Class
III	Standing tree, living or dead, with a diameter >15 cm and < 40 cm at *diameter breast height.*	Standing tree, living or dead, with a diameter >15 cm and < 40 cm at *diameter at root crown*.	**10 meter radius** around 50P marker	Crown Position Class Code
IV	Standing tree, living or dead, with a diameter at ≥ 40 cm *diameter breast height*.	Standing tree, living or dead, with a diameter at ≥ 40 cm *diameter at root crown*.	**10 meter radius** around 50P marker	Crown Position Class Code

Monitoring Trees

Equipment

- Two 15 meter Metric/English tapes
- Two Tree Go-No-Go's
- Tree Key
- Yardstick

Procedure

1. Read through the whole procedure once before starting the procedure. Ask questions for clarification if necessary.

2. Review the Tree Key.

3. Review the ***Go-No-Go*** description found below.

4. Designate two students to use the Go-No-Go's, one student as a recorder, and two students to measure the distance of the trees from the 50P marker (using the 15 meter tapes).

5. Each Go-No-Go student should partner with a student carrying a measuring tape. One pair of these students will be responsible for all the Class I trees within a 5 meter radius sample area around the 50P marker. The other pair will be responsible for the Class II, Class III, and Class IV trees within a 10 meter radius sample area around the 50P marker.

5. Each pair will report the following information to the recorder:
   i. Tree species
   ii. Is the tree alive or dead? If it is a Class I or Class II tree, only record it if it is alive. If it is a Class III or Class IV tree, circle L (live) or D (dead).
   iii. Rough estimate of height for Class I and II trees- use the yardstick and height class descriptions on page 2 of the Data Sheet.
   iv. Crown Position Class Code for Class III and Class IV trees- use the Crown Position Diagrams on page 4 of the Data Sheet.

Class I Trees

6. Refer to **Student Rapid Assessment Plot Overview** for help. Face away from 0P. Starting on the right side of the 0P-50P transect, move clockwise around the 5 meter radius sample area. One way to do this is to extend the tape measure to 5 meters and walk in a circle to decide which trees are included. When someone reaches a tree, determine what kind of tree it is using the Tree Key. Measure the diameter using the Go-No-Go to determine the Diameter Class:

Monitoring Trees

i. For ponderosa pine, pinyon pine, and gambel oak, measure the diameter at breast height, 1.37 meters (4.5 feet) from the ground.
ii. For Utah juniper, measure diameter at the point where the tree stem emerges from the ground.

7. Also, roughly estimate the height of the tree using the yard stick. Report this data to the recorder and help him/her determine Height Class using the descriptions on page 2 of the Data Sheets.

8. Continue moving around the plot, measuring and recording trees. Report tree data to the recorder.
   *The recorder should place a tally mark for each tree fitting a description under Tally. For example, if two ponderosa Diameter Class I trees are in Height Class 1, don't re-write the information on a new line for the second tree. Just place another tally mark by the first tree in that species and class. When finished, count up the tally marks for each line and write the number under Total. Remember to draw a tally mark for each tree- even the first!

Class II, III, and IV Trees

9. Refer to **Student Rapid Assessment Plot Overview** for help. Face away from 0P. Starting on the right side of the 0P-50P transect, move clockwise around the 10 meter radius sample area. One way to do this is to extend the tape measure to 10 meters and walk in a circle to decide which trees are included. When someone reaches a tree, determine what kind of tree it is using the Tree Key. Measure the diameter using the Go-No-Go to determine the Diameter Class:
   i. For ponderosa pine, pinyon pine, and gambel oak, measure the diameter at breast height, 1.37 meters (4.5 feet) from the ground.
   ii. For Utah juniper, measure diameter at the point where the tree stem emerges from the ground.

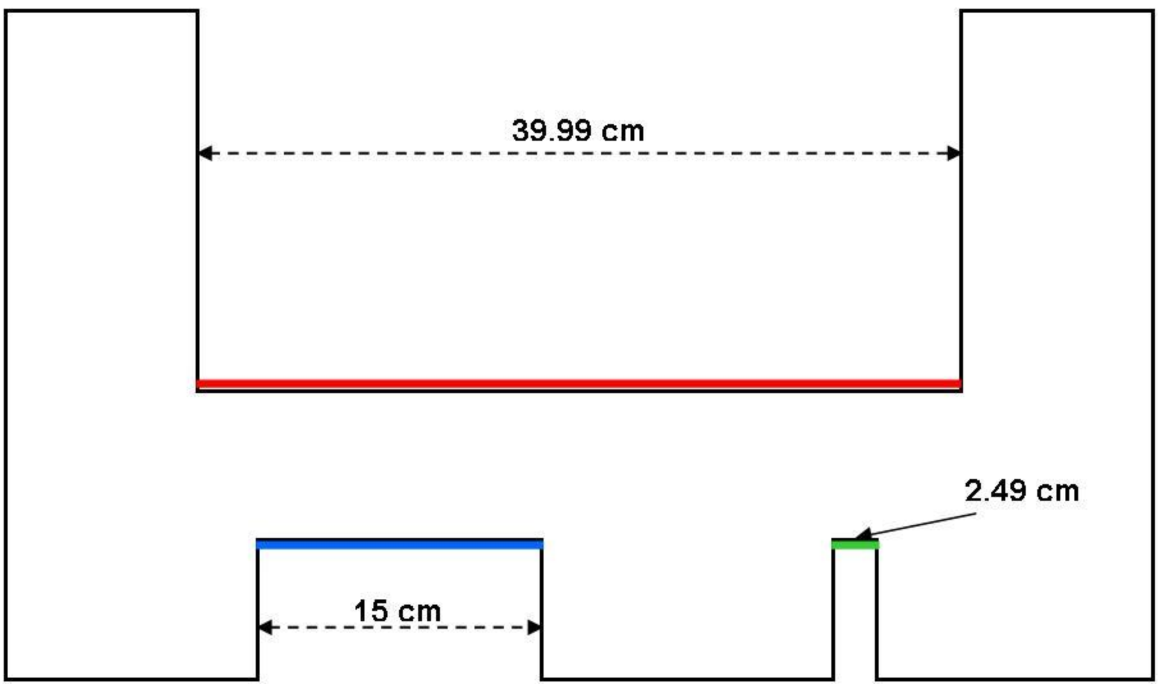
10. Also, roughly estimate the height of Diameter Class II trees using the yard stick.
    - Report the height to the recorder and help him/her determine Height Class (based on descriptions on page 2 of Data Sheet).
    - Determine the Crown Class Code for Diameter Class III and IV trees using the Diagrams in the Data Sheets.

11. Continue moving around the plot, measuring and recording trees. Report tree data to the recorder.

Monitoring Trees

*The recorder should place a tally mark for each tree fitting a description under Tally. For example, if two ponderosa Diameter Class I trees are in Height Class 1, don't re-write the information on a new line for the second tree. Just place another tally mark by the first tree in that species and class. When finished, count up the tally marks for each line and write the number under Total. Remember to draw a tally mark for each tree- even the first!

Tree Go-No-Go



A Go-No-Go is a tool used to separate items into size classes. In this case, the Go-No-Go has three notches that correlate to three Tree Diameter Classes. The smallest notch corresponds to Class I, the next largest corresponds to Class II, the largest Class III. Trees that are too large to fit in the last notch are Class IV trees. To determine what class a tree belongs to, start by using the smallest notch. If the tree does not fit into the smallest notch, move to the next largest notch. This is very important: **the Go-No-Go tool must be used from smallest notch to largest notch**. The notch that fits the tree correlates to the tree class.

For example, if your group finds a tree in the sample area that does not fit in the smallest notch but fits in the next largest notch, the tree would be a Class II tree.

You can create your own Tree Go-No-Go by cutting a piece of cardboard with the size notches shown above.

SRAP-2 MONITORING TREES DATA SHEETS- PONDEROSA EXAMPLE

Plot ID PiPO 41 Rx / Thin / Unknown (circle one) Date 10/10/10
Treatment Unit BUGGELN Recorders JIM, MARY

Treatment Status: PRE POST ____

Determine FOUR THINGS about each tree:

1) **Species** using the Tree Key
2) **Dead** or **Alive**?
3) **Diameter Class** (I, II, III, or IV) using the Go-No-Go
4) **Height Class** (0.6-10, see bottom of sheet 2) using the yardstick

*Note: Diameter Class and Height Class are two separate measurements. Diameter Class (using the Go-No-Go) determines which chart tree data is recorded in. Height Class is measured after determining Diameter Class.

Tally each tree in the **same Species + Height Class**- even the first one! Otherwise your total counts will be off by one.

Area Sampled: 5 meter radius from 50P for Class I.
Area Sampled: 10 meter radius from 50P for Class II-IV.

Class I – Seedlings (<2.5 cm)

Species	Status (Only Alive)	Height Class (use descriptions below)	Tally (Tally mark for EACH tree- even the first!)	Total
Ponderosa	(L)	0.6	III	3
Ponderosa	(L)	1	IIII	4
Ponderosa	(L)	3	I	1
Ponderosa	(L)	2	I	1
	L			
	L			
	L			
	L			
	L			
	L			

Class II – Sapling (≥2.5 cm and ≤15 cm)				
Species	Status (Only Alive)	Height Class (use descriptions below)	Tally (Tally mark for EACH tree- even the first!)	Total
Ponderosa	(L)	4	|	1
Ponderosa	(L)	3	| |	2
Ponderosa	(L)	1	|	1
	L			
	L			
	L			
	L			
	L			
	L			

Height[1] classes descriptions (in meters):

0.6 = < 0.6 **1** = 0.6 – 1 **2** = 1.1 – 2 **3** = 2.1 – 3 **4** = 3.1 – 4 **5** = 4.1 – 5
6 = 5.1 – 6 **7** = 6.1 – 7 **8** = 7.1 – 8 **9** = 8.1 – 9 **10** = 9.1+

[1] Roughly estimate height from the ground up using the yardstick.

Class III – Intermediate (>15 cm and < 40 cm)				
Species	Status (Alive or Dead)	Crown Position Class Code (use diagram below)	Tally (Tally mark for EACH tree- even the first!)	Total
Ponderosa	(L) D	CD	||||	4
Ponderosa	(L) D	D	|	1
Ponderosa	(L) D	CD	||	2
Ponderosa	L (D)	BAD	|	1
	L D			
	L D			
	L D			
	L D			
	L D			

Class IV – Large (≥ 40 cm)				
Species	Status (Alive or Dead)	Crown Position Class Code (use diagram below)	Tally (Tally mark for EACH tree- even the first!)	Total
Ponderosa	(L) D	D	|	1
Ponderosa	L (D)	SC	||	2
Ponderosa	(L) D	CD	|	1
Ponderosa	L (D)	BAD	|	1
	L D			
	L D			
	L D			
	L D			
	L D			

SRAP-2 MONITORING TREES DATA SHEETS- PINYON/JUNIPER EXAMPLE

Plot ID PIED13 Rx / Thin / Unknown (circle one) Date 10/10/10
Treatment Unit SHOSHONE Recorders STEVE, MARY

Treatment Status: PRE POST ____

Determine FOUR THINGS about each tree:

1) **Species** using the Tree Key
2) **Dead** or **Alive**?
3) **Diameter Class** (I, II, III, or IV) using the Go-No-Go
4) **Height Class** (0.6-10, see bottom of sheet 2) using the yardstick

*Note: Diameter Class and Height Class are two separate measurements. Diameter Class (using the Go-No-Go) determines which chart tree data is recorded in. Height Class is measured after determining Diameter Class.

Tally each tree in the **same Species + Height Class**- even the first one! Otherwise your total counts will be off by one.

Area Sampled: 5 meter radius from 50P for Class I.
Area Sampled: 10 meter radius from 50P for Class II-IV.

Class I – Seedlings (<2.5 cm)

Species	Status (Only Alive)	Height Class (use descriptions below)	Tally (Tally mark for EACH tree- even the first!)	Total
Pinyon Pine	(L)	0.6	||||||	6
Pinyon Pine	(L)	1	||	2
Juniper	(L)	1	|	1
Gambel Oak	(L)	0.6	||	2
	L			
	L			
	L			
	L			
	L			
	L			

Class II – Sapling (≥2.5 cm and ≤15 cm)				
Species	Status (Only Alive)	Height Class (use descriptions below)	Tally (Tally mark for EACH tree- even the first!)	Total
Pinyon	(L)	2	I	1
Juniper	(L)	1	II	2
Juniper	(L)	1	II	2
	L			
	L			
	L			
	L			
	L			
	L			

Height[1] classes descriptions (in meters):

Class 0.6 = < 0.6m   Class 1 = 0.6 – 1m   Class 2 = 1.1 – 2m
Class 3 = 2.1 – 3m   Class 4 = 3.1 – 4m   Class 5 = 4.1 – 5m
Class 6 = 5.1 – 6 m   Class 7 = 6.1 – 7m   Class 8 = 7.1 – 8m
Class 9 = 8.1 – 9m   Class 10 = 9.1+m

[1] Roughly estimate height from the ground up using the yardstick.

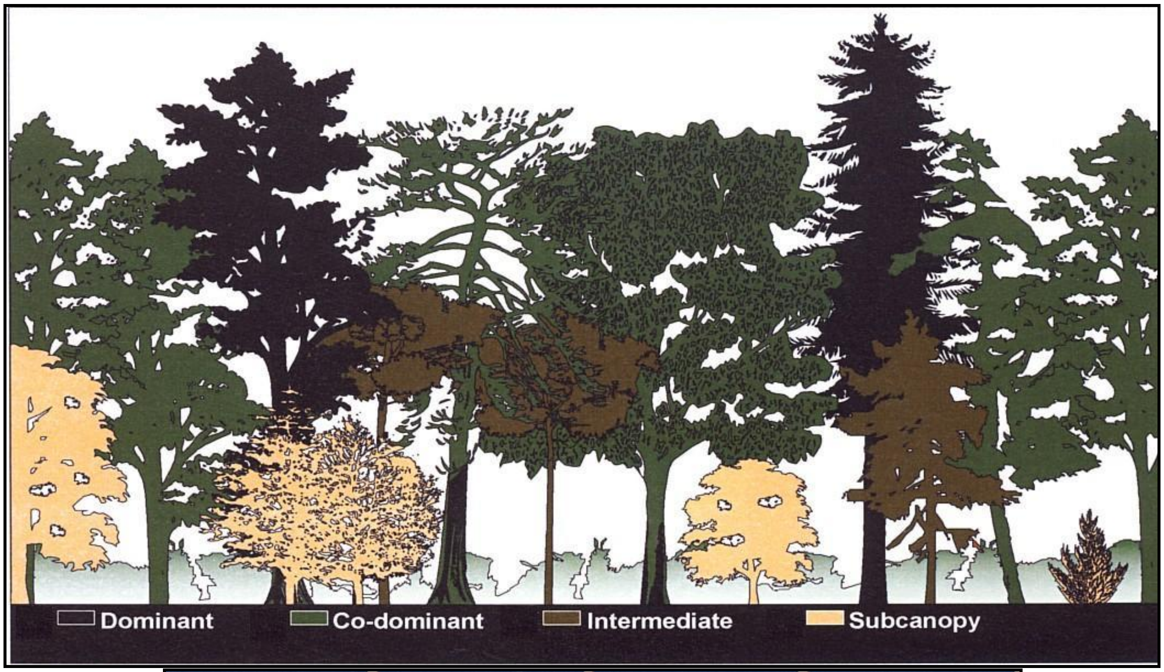
Class III – Intermediate (>15 cm and < 40 cm)				
Species	Status (Alive or Dead)	Crown Position Class Code (use diagram below)	Tally (Tally mark for EACH tree- even the first!)	Total
Pinyon	L (D)	DD	|	1
Juniper	(L) D	SC	| | |	3
Juniper	(L) D	SC	|	1
Gambel oak	(L) D	SC	| |	2
	L D			
	L D			
	L D			
	L D			
	L D			

Class IV – Large (≥ 40 cm)				
Species	Status (Alive or Dead)	Crown Position Class Code (use diagram below)	Tally (Tally mark for EACH tree- even the first!)	Total
Gambel oak	(L) D	D	|	1
	L D			
	L D			
	L D			
	L D			
	L D			
	L D			
	L D			
	L D			

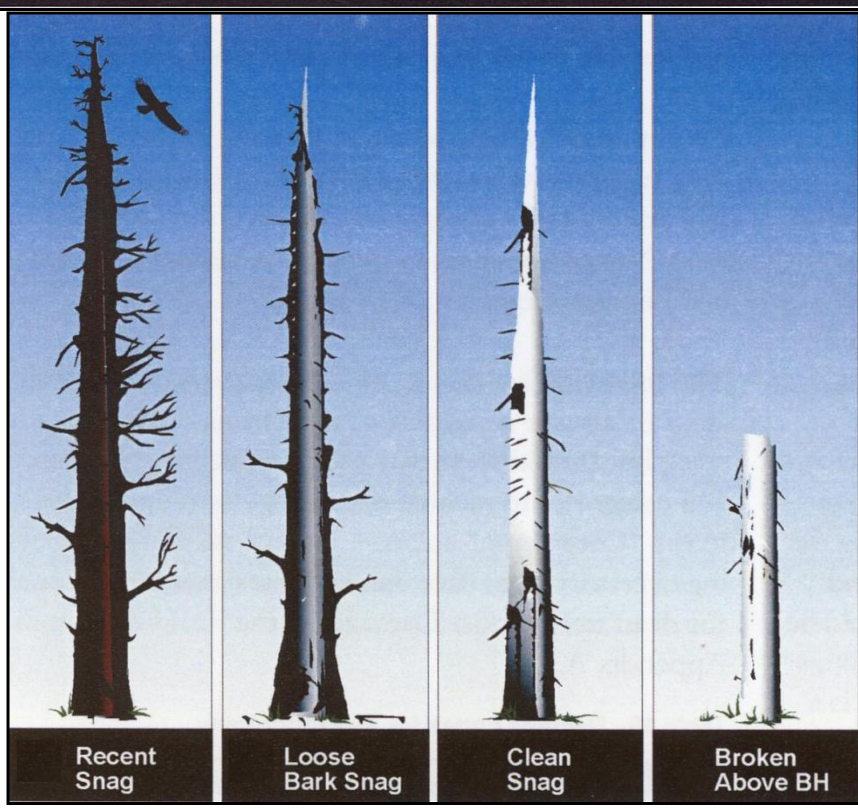
Crown Position Class codes:

D = Dominant C = Codominant I = Intermediate SC = Subcanopy
O = Open Grown RS = Recent Snag LBS = Loose Bark Snag CS = Clean Snag
BAD = Broken Above DBH DD = Dead and Down

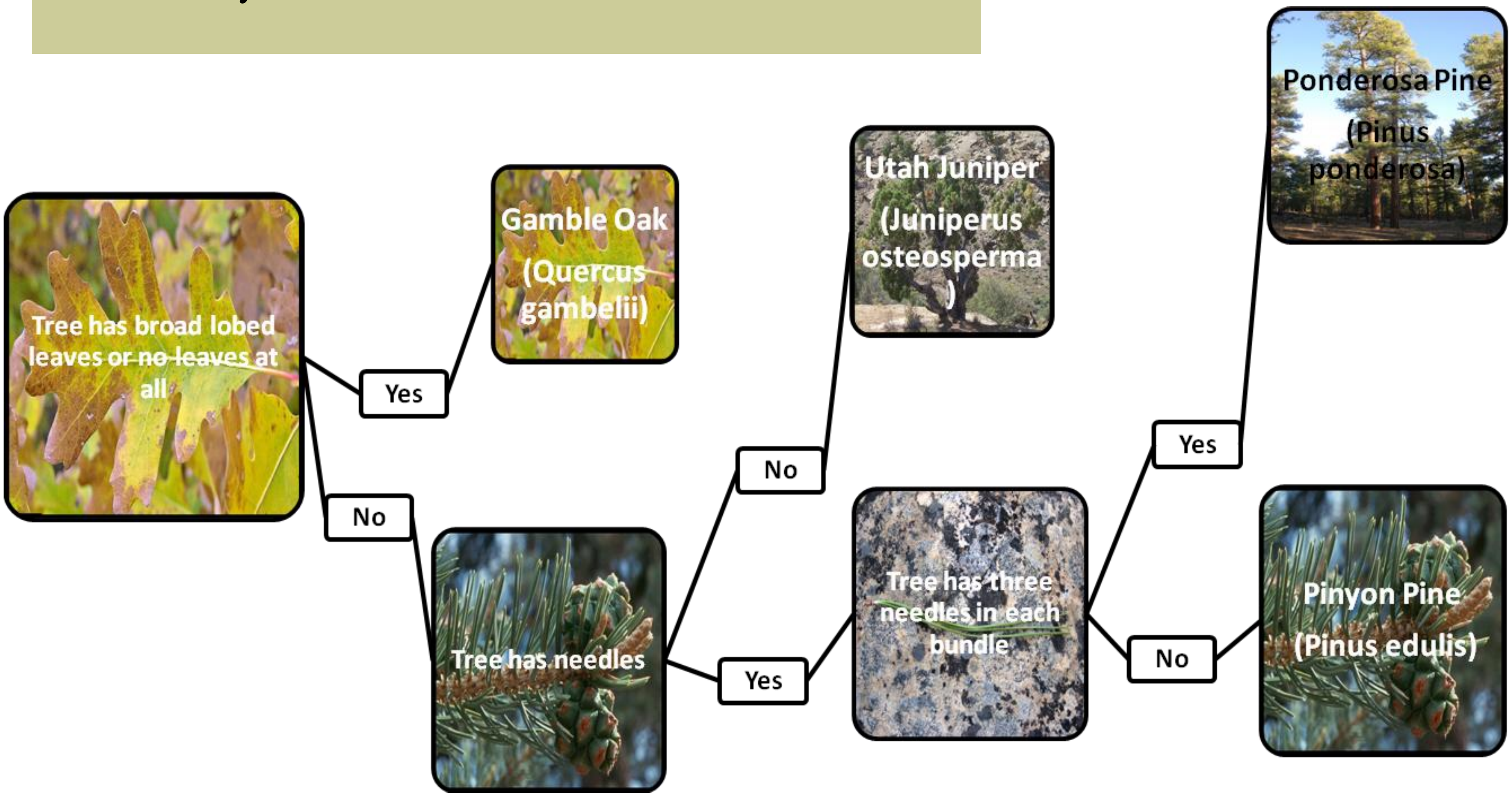
Alive



Dead



Tree Key


Tree has broad lobed leaves or no leaves at all
Yes
Gamble Oak (Quercus gambelii)
No
Tree has needles
No
Utah Juniper (Juniperus osteosperma)
Yes
Tree has three needles in each bundle
Yes
Ponderosa Pine (Pinus ponderosa)
No
Pinyon Pine (Pinus edulis)

Shrubs and Herbaceous Plants

A shrub is a multi-stemmed woody plant that does not grow to the height of a tree. Examples at Grand Canyon National Park include Cliff Rose and Mountain Mahogany. Herbaceous Plants are non-woody. Examples include Blue Grama (a grass) and Lupine (a wildflower).

Shrubs and herbaceous plants can influence fire behavior on the ground. These two fuels can also act as ladders to move fire from the ground level up to smaller trees and then into the canopy. In this protocol, the amount of ground covered by shrubs and herbs will be measured. In addition, the presence or absence of invasives will be recorded.

Equipment

- Tape measure
- Dichotomous key
- Pin flags
- Calculators
- Invasive Plant Guide

Procedure

1. Measure 10 meters from the 50P marker in four directions: you are trying to make a plus sign 20 meters across and 20 meters high with the 50P marker at the center.

2. To start, at the 50P marker use the tape to measure 10 meters towards 0P. Put a pin flag at the 10 meter mark.

3. Start at 50P again and measure 10 meters in the opposite direction of the 0P marker. Mark the 10 meter mark with a pin flag.

4. Repeat this measuring and marking to create the other half of the plus sign. See the set-up diagram for help.

5. Visualize the circle created by connecting the four pin flag points. Imagine you are separating this 10 meter radius plot into four quarters.

6. Stand at the 50P marker. Orient the <u>Herbaceous Plant Plot Graph</u> (make sure you are looking at the data sheet so that it matches the plot). Looking at the plot, shade in areas on the graph that are covered by herbaceous plants. <u>Herbaceous plants include grasses, wildflowers, and other non-woody plants.</u>

Shrubs and Herbaceous Plants

7. Next, repeat Step 7 for shrubs on the Shrubs Plot Graph. Shrubs are short, squat, woody plants.

8. Use the Invasive Plant Guide to determine if there are any invasives within the plot. List any invasive plants you find on the top of the data sheet.

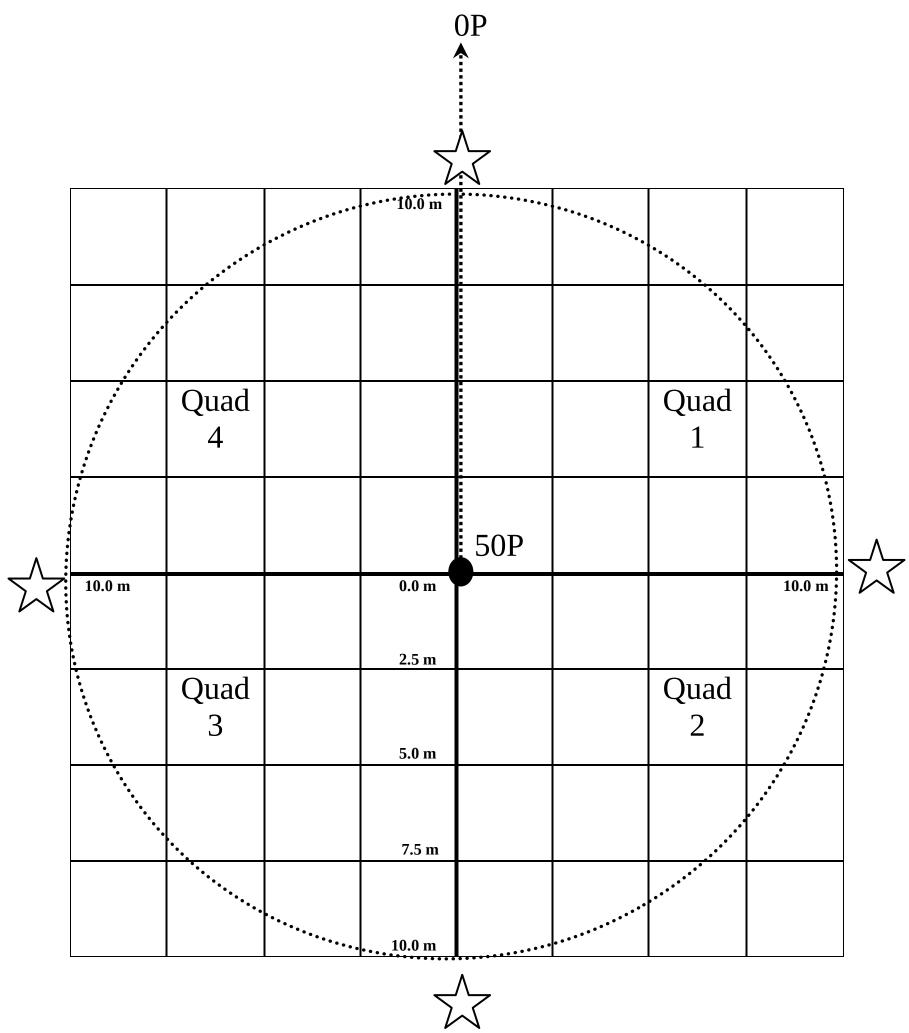
9. Repeat Step 7 for invasive plants and shade in areas on the Invasive Plot Graph to show where they are located. Use a different type of mark for each species you find. For example, use dots for cheat grass and dashes for mullein. Record which mark goes with each species in the Key under the graph.

10. The shaded areas on each graph correspond to herbaceous plant, shrub, or invasive coverage. Use the calculations on the data sheet to help you figure out *percent coverage* for each type of plant.

11. At the top of the data sheet, locate the range that the herbaceous plant percent coverage falls into. Mark this range with an X. Repeat for shrubs.

12. For invasive plants, determine the percent coverage for each species. At the top of the data sheet, mark the range that each species' percent coverage falls into. A separate percent coverage is recorded for each species found.

Shrubs and Herbaceous Plants Diagram



Place pin flags 10 meters from 50P in four directions (where the stars are located on the diagram). Don't use the compass- just make one line parallel to the transect and one line perpendicular to it. Imagine a circle connecting the four points. This is a 10 meter radius circle.

Only shrubs or herbaceous plants located within this circle should be counted.

South Rim Invasive Plant Guide

Diffuse Knapweed (*Centaurea diffusa*)

Diffuse knapweed is greyish/ green and grows 4-24 inches tall. Its flowers can grow alone or in clusters of 2-3 at the ends of the branches. The flower petals are white, rose-purple, to lavender.

Rush Skeletonweed (*Chondrilla juncea*)

Rush skeletonweed has many branched, wiry stems that range from 1 to 4 feet tall. There are coarse, reddish downward-pointing hairs at the base of the single flowering stem, and small yellow flowers.

Scotch Thistle (*Onopordum acanthium*)

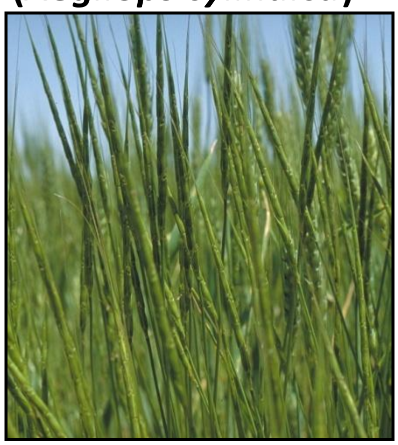
Scotch Thistle is grayish and furry. It has soft, broad, spiny leaves, and it ranges in height from 2-12 feet. The flowers are violet to reddish and look like a shaving brush up to 2 inches in diameter.

South Rim Invasive Plant Guide

Bull Thistle (*Cirsium vulgare*)

The Bull Thistle's stem is 2-5 feet tall with many spreading branches. Leaves are bumpy and hairy and very prickly. The flowers are dark purple and clustered at the ends of the branches.

Jointed Goatgrass (*Aegilops cylindica*)



This grass has jointed, cylindrical spikes.

Puncturevine (*Tribulus terrestris*)

This plant creates a mat-like appearance close to the ground. It has trailing stems which can reach up to 5 feet in length. Its flowers are yellow with five petals.

South Rim Invasive Plant Guide

Mediterranean Sage (*Salvia aetheopsis*)

The leaves of this plant are furry. It has multi-branched stems with many small white flowers.

Dalmation Toadflax (*Linaria dalmatica*)

This plant has triangular leaves that feel waxy or rubbery. It has bright yellow flowers that have upper and lower lobes.

South Rim Invasive Plant Guide

Mullein (*Verbascum thapsus*)

This tall plant has furry leaves and many yellow flowers at the top of its stalk.

Horehound (*Marrubium vulgare*)

Horehound can grow up to 3 feet tall. Its leaves are whitish and woolly. Its flowers are clustered densely and are small and white.

Photo Credits for South Rim Invasive Plant Guide

Diffuse Knapweed
USDA Plant National Invasive Species Information Center
http://www.invasivespeciesinfo.gov/plants/diffknapweed.shtml

Rush Skeletonweed
Wind Cave National Park
http://www.nps.gov/wica/naturescience/images/Rush-Skeletonweed.jpg
Washington State Noxious Weed Control Board
http://www.nwcb.wa.gov/weed_info/Images/weedphotos/Rush-Skeletonweed---Leaf-03-07.jpg

Scotch Thistle
Stanford University Photography
http://www.stanford.edu/~grg/photography/flowers.html

Bull Thistle
Study of Northern Virginia Ecology,
http://www.fcps.edu/islandcreekes/ecology/bull_thistle.htm

Jointed Goatgrass
Texas Weed Information Group, Texas A&M University
http://twig.tamu.edu/jointed_goatgrass_aegilops_cylindrica_host_006.jpg
Washington State University Extension
http://jointedgoatgrass.wsu.edu/jointedgoatgrass/gallery/index.htm

Mediterranean Sage
Center for Invasive Species and Ecosystem Health
http://www.invasive.org/images/768x512/0022068.jpg
http://www.invasive.org/images/768x512/0021072.jpg

Puncturevine
Wikipedia
http://en.wikipedia.org/wiki/File:Starr_030612-0063_Tribulus_terrestris.jpg

Dalmation Toadflax
USDA Plant National Invasive Species Information Center
http://www.invasivespeciesinfo.gov/plants/toadflax.shtml

Mullein
Wikipedia
http://en.wikipedia.org/wiki/Verbascum_thapsus

Horehound
USDA Plant Database
http://plants.usda.gov/java/largeImage?imageID=mavu_003_ahp.jpg

SRAP-3

SHRUBS & HERBACEOUS PLANTS DATA SHEET- PONDEROSA EXAMPLE

Plot ID PIPO 41 Rx / Thin / Unknown (circle one) Date 10/10/10
Treatment Unit BUGGELN
Recorders JIM, Mary

Treatment Status: PRE POST ____

Area Sampled: 10 meter radius from 50P for all observed herbaceous, shrub, & invasive species

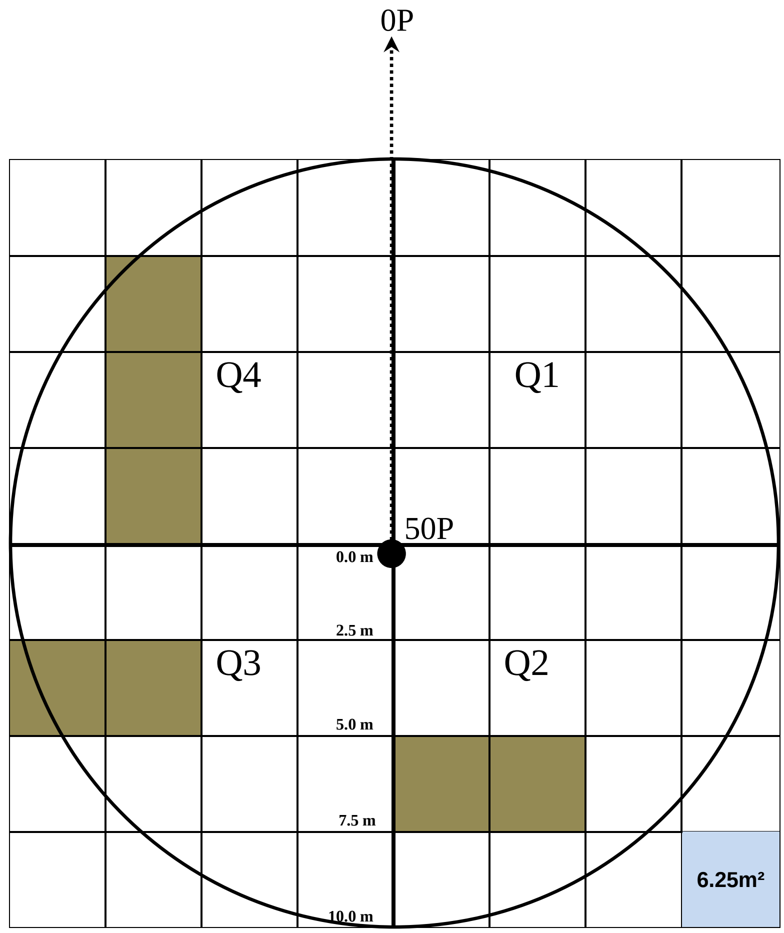
PERCENT COVER

	0%	0-5%	6-25%	26-50%	51-75%	76-95%	96-100%
HERBS			X				
SHRUBS		X					

Invasive Species	0-5%	6-25%	26-50%	51-75%	76-95%	96-100%
Scotch Thistle	X					
Diffuse Knapweed	X					

Any invasives present?
Y / N

Herbaceous Plot Graph



Calculations for Herbaceous Plants % Coverage

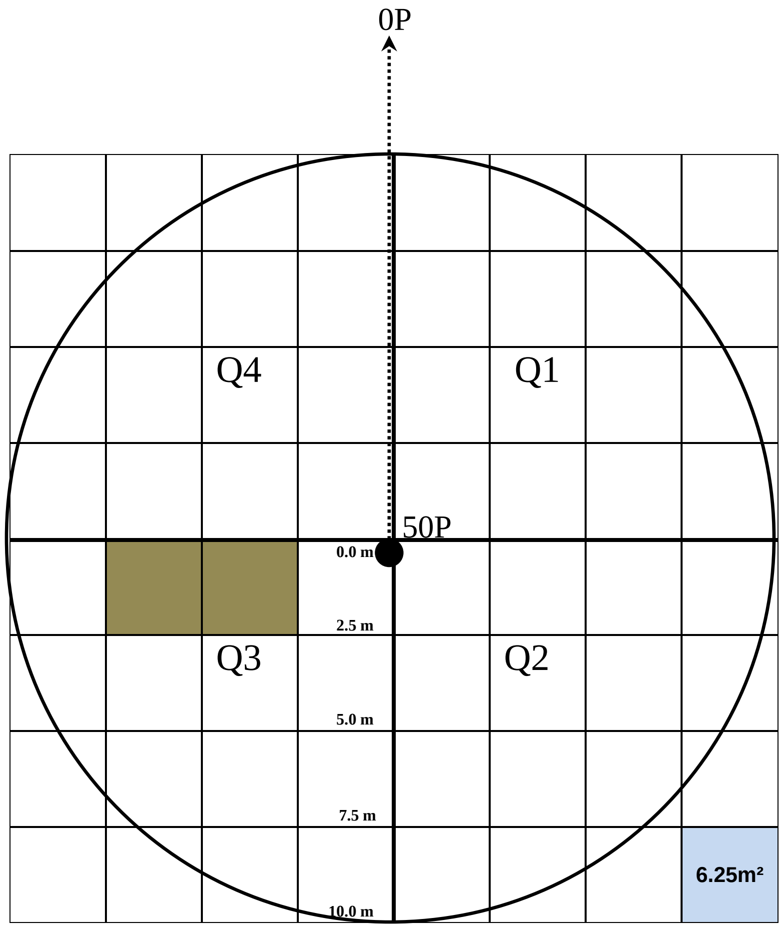
Shaded Squares ≈ __7___ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = _314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Herbs % Coverage = ___13.9 %______

Shrub Plot Graph



Calculations for Shrubs % Coverage

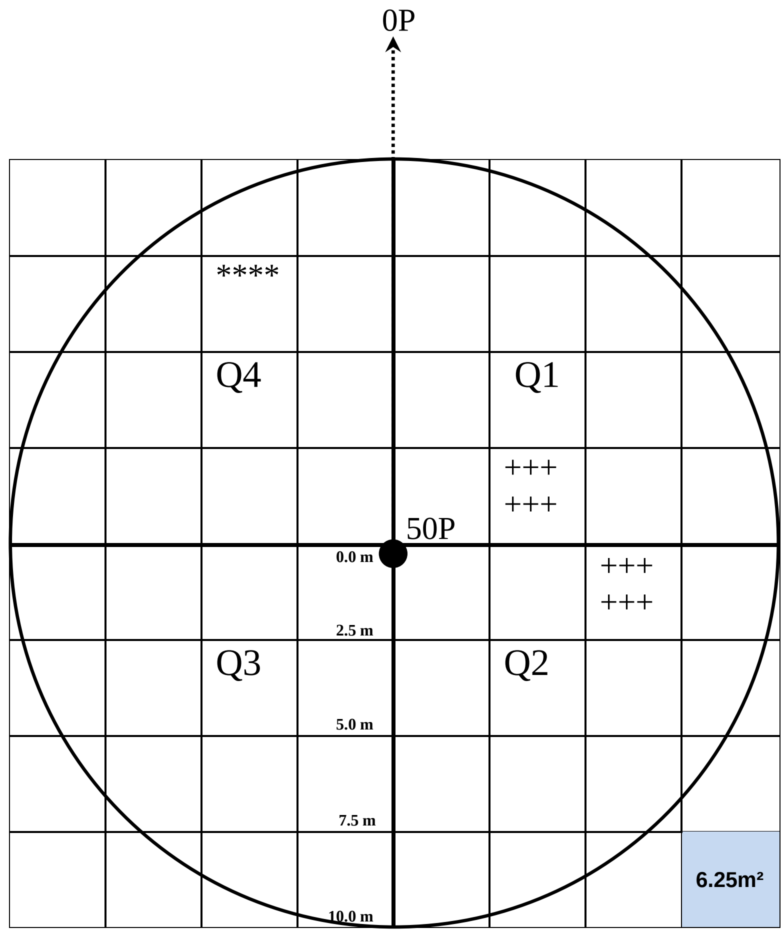
Shaded Squares ≈ ___2__ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = 314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Shrubs % Coverage = ___3.9%__________________

Invasive Plot Graph



Key:

Species	Mark Used
Diffuse Knapweed	****
Scotch Thistle	+++++
____________	____________
____________	____________

Calculations for Invasive % Coverage

Species ___________Diffuse Knapweed___

Shaded Squares ≈ ___1__ X 6.25 m^2 ≈ A 1

Area of Plot = πr^2 = _314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Exotics % Coverage = _____1.9%______

....

Species _____Scotch Thistle__________

Shaded Squares ≈ __2___ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = _314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Exotics % Coverage = ______3.9%_____

....

Species ________________

Shaded Squares ≈ _____ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = _314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Exotics % Coverage = ___________

SRAP-3

SHRUBS & HERBACEOUS PLANTS DATA SHEET- PINYON/JUNIPER EXAMPLE

Plot ID PIED13 Rx / Thin / Unknown (circle one) Date 10/10/10

Treatment Unit SHOSHONE

Recorders JIM, MARY

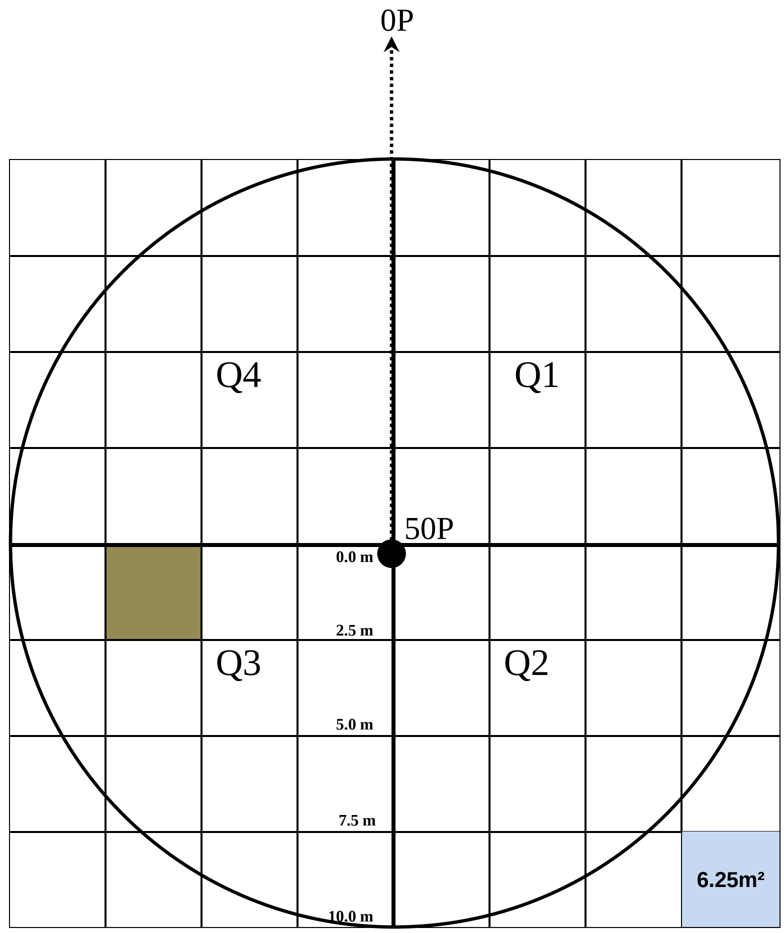
Treatment Status: PRE POST ____

Area Sampled: 10 meter radius from 50P for all observed herbaceous, shrub, & invasive species

	PERCENT COVER						
	0%	0-5%	6-25%	26-50%	51-75%	76-95%	96-100%
HERBS		X					
SHRUBS		X					

Invasive	Species	0-5%	6-25%	26-50%	51-75%	76-95%	96-100%
Any invasives present?							
Y / **N**							

Herbaceous Plot Graph



Calculations for Herbaceous Plants % Coverage

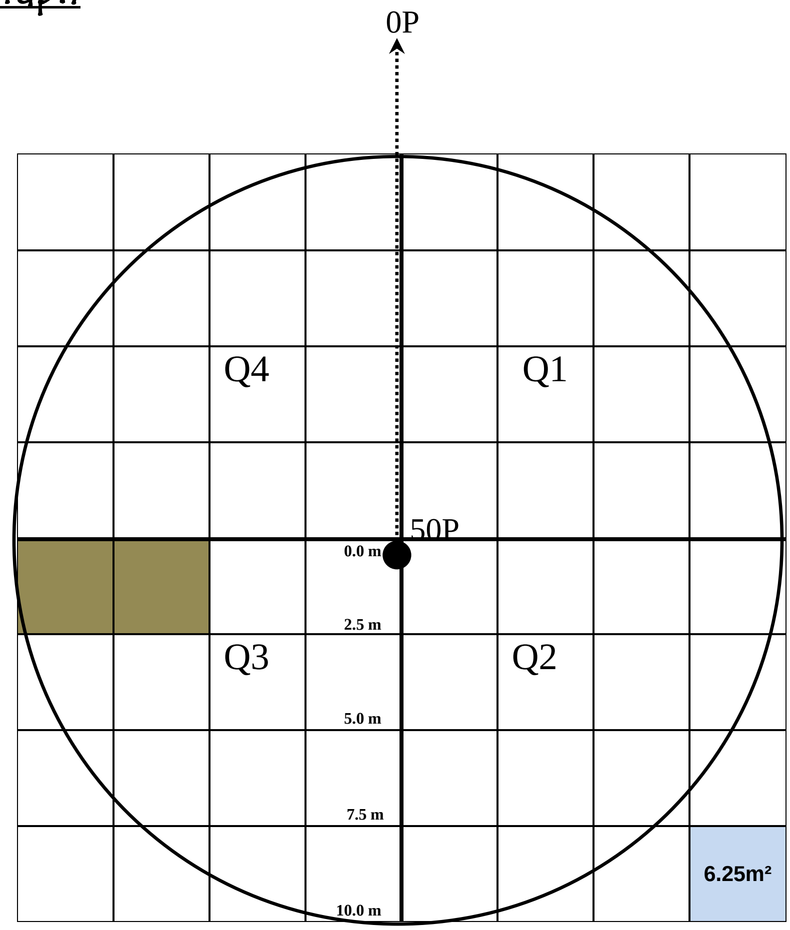
\# Shaded Squares ≈ ___1__ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = _314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Herbs % Coverage = _____1.9%______

Shrub Plot Graph



Calculations for Shrubs % Coverage

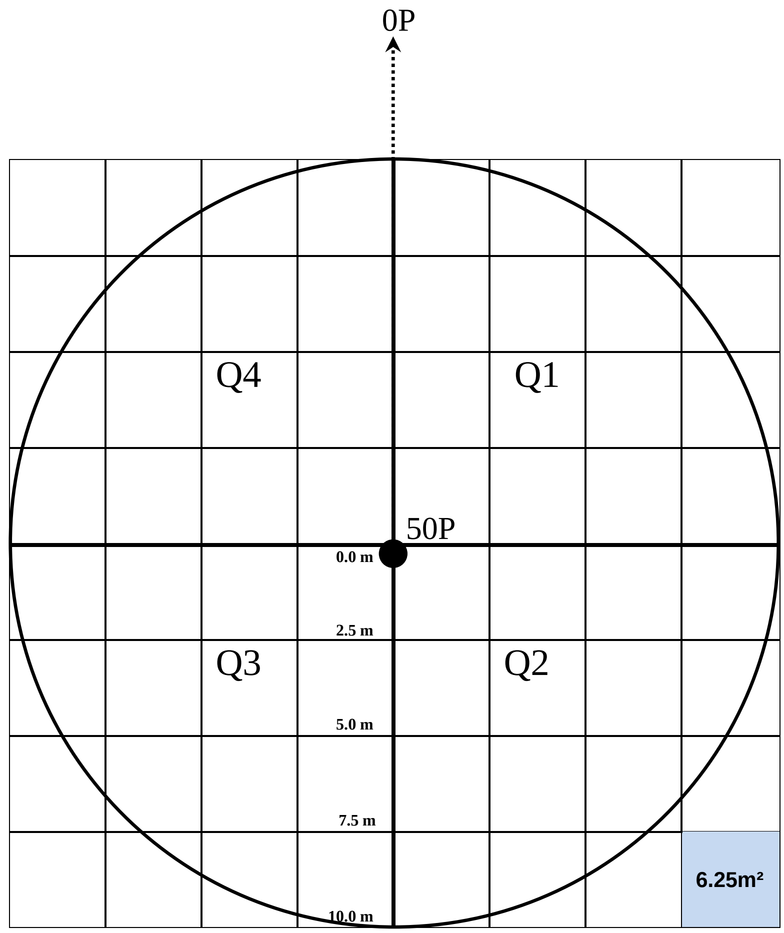
Shaded Squares ≈ _2____ X 6.25 m² ≈ A1

Area of Plot = πr^2 = _314.16 m²

% Coverage ≈ A1 ÷ 314.16 m² X 100

Shrubs % Coverage = ___3.9%________________

Invasive Plot Graph



Key:

Species	Mark Used
N/A	________
________	________
________	________
________	________

Calculations for Invasive % Coverage

Species _________N/A______

Shaded Squares ≈ _____ X 6.25 m^2 ≈ A 1

Area of Plot = πr^2 = 314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Exotics % Coverage = ___________

....

Species _______________

Shaded Squares ≈ _____ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = 314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Exotics % Coverage = ___________

....

Species _______________

Shaded Squares ≈ _____ X 6.25 m^2 ≈ A1

Area of Plot = πr^2 = 314.16 m^2

% Coverage ≈ A1 ÷ 314.16 m^2 X 100

Exotics % Coverage = ___________

Field Glossary

1, 10, 100, 1000 Hour/Hr: A fuel classification based on the amount of time (in hours) the fuel needs dry and reach an equilibrium with the surrounding environmental conditions. For example, a twig could be a *1 hour fuel* because it only needs 1 hour to dry to a moisture level similar to the surrounding atmosphere.

Aspect: The direction that a surface is facing.

Cardinal direction: North, South, East, or West.

Clinometer: A tool used to measure percent slope of an area.

Crown position: Crown position is a relative measurement that describes how much a tree has to compete with other trees for light.

Dead Fuels: Fuels with no living tissue that gain moisture from their environment (relative humidity and precipitation) and lose it through solar radiation.

Diameter: A straight line passing through the center of a circle.

Diameter at Breast Height (DBH): The diameter of a tree or shrub measured at 1.37 meters (4.5 feet) above ground.

Diameter at root crown: The diameter of a tree or shrub measured where the tree stem emerges from the ground.

Downed woody debris: Fuels on the ground that are not duff or litter, including twigs, branches, and logs.

Duff: The layer of decomposing organic materials lying below the litter layer and above the mineral soil.

Forest composition: A description of the sizes, relative ages, and species of vegetation in a forest.

Fuel: Combustible material.

Herbaceous plants: Plants without a woody structure, including grasses and wildflowers.

Field Glossary

Invasive: A species not native to a given area, which may be competing unfavorably with native species for resources.

Litter: Top layer of the forest floor composed of loose dead sticks, twigs, and recently fallen leaves or needles.

Live Fuels: Plants with live tissues that actively gain water to support life function.

Mineral soil: Any soil consisting primarily of mineral material (such as sand or clay) rather than organic matter.

Peep sight: A notch in the cover of a compass used to align the compass holder with an object in the distance.

Percent coverage: The amount of area covered by a certain item, such as grass, expressed between 0% (no item present) and 100% (total coverage).

Radius: A line connecting the center of a circle with any point on its circumference.

Rapid Assessment Plot: A ground plot used by field technicians to quickly measure specific characteristics of an area, such as fuel loads and forest composition.

Rotten: A word used to describe downed logs that are decomposing.

Scale: A way to describe the dimensional relationship between a representation (such as a map) to that which it represents (the area on the map). Example- 1 inch: 1 mile.

Shrub: A woody plant of relatively low height, having several stems arising from the base and lacking a single trunk; a bush.

Slope: The slant, or deviation from the horizontal, of a given area.

Sound: A word used to describe downed logs that are intact and not decomposing.

Transect: A line used for ecological measurements.

Universal Trans Mercator (UTM): A map projection system for global mapping, used in place or to complement *degrees latitude and longitude*. UTM divides the world into 60 zones, each of 6-degrees-longitude width.

Handout: Field Data Analysis

Question:

Think about the question you wanted to investigate and the prediction you made during the Field Experience. Refer back to your **Making Predictions about Field Data Handout**.

What was your question?

Hypothesis:

What was your prediction?

Turn this prediction into a hypothesis. **A hypothesis describes what you think will happen *and why*.** Write your hypothesis here:

Make sure your hypothesis is testable. That is, make sure there is data available that can tell whether your hypothesis is supported or not. For example, your class did not collect data about wildlife, so your hypothesis could not be the following:
I think that a bigger deer population will mean less fuels on the forest floor because deer eat the fuels.

Design:

You will be using the data gathered by your class as well as extra data provided.

Conduct Research:

Gather data from your class's field data sheets and the data sheets provided. Write down all of the pieces of data you will need. For example, if your hypothesis was:
I think that a greater number of Class IV trees will mean a greater number of logs on the ground because the logs are pieces of the trees, then you would need to know the number of Class IV trees on each plot and the number of 1000 hour fuels (logs) on each

Handout: Field Data Analysis

plot. Record which data sheet pieces of information were taken from, in case you need to go back and check the data.

Data Analysis:

Analyze the pieces of data you have gathered. You may need to manipulate some pieces of information, for example finding the mean, median, or mode of sets of data. Using the information you have gathered, does you hypothesis make sense? (I.e., was your answer to the original question on track or completely off?) Remember: you can never prove or disprove a hypothesis. However, by analyzing your data you can get a clearer idea of what effects different variables can have.

Reflect on Results:

On a separate sheet of paper, present your findings in a clear way. This might entail using a graph or table to show a trend or comparison. Write a one or two page summary stating your findings.

Include the following information:
What made you interested in the topic
Your hypothesis
What background information you have supporting your hypothesis
What data you analyzed
Was your hypothesis supported or not?
A short discussion about why your hypothesis was or was not supported
Any future directions you might like to take in fire ecology research (for example, would you have liked to collect data about wildlife and fire?)

Overview of Post-Field Trip Activities

This overview describes the possible extension activities available for classroom use after the *Fire Ecology on the Rim* program. Feel free to pick and choose which activities work best. However, it is strongly suggested that students complete the Field Data Analysis in order to gain closure on the program.

Theme: Fire is a natural phenomenon that can have desirable or undesirable effects on the landscape. By studying environmental conditions and fire behavior, fire staff can better understand how fire and the landscape interact.

Objectives: Students will be able to
… list the parts of the fire triangle
… describe how weather, topography, and fuels can influence fire behavior
… explain the difference between unplanned and planned wildland fires
… describe how fire affects plants, wildlife, soil, air, and water
… identify ways in which ponderosa pines adapt to a frequent-fire habitat
… explain why fire staff collect data about forests and fire
… perform data collection following established protocols
… use the collected data to answer a research question
… explain how different groups of people (shareholders) feel about fire

***Bolded objectives should be specifically addressed in post-field trip activities.**
*****Not-bolded objectives are addressed during the field trip but should be reviewed afterward.

Materials:

- Digital copy of *Fire Ecology on the Rim* program
- Data collected by students on field trip
- Access to computers with Microsoft Office and internet capability
- Paper and pencils

Potential Activities (Choose to meet your needs):

Field Data Analysis. Use **Field Protocols**, **Making Predictions About Field Data**, **Field Data Analysis Handout**, **Student-Collected Data,** and **Ponderosa and Pinyon Juniper Field Data.**

Use student-collected data and extra data provided to ask and answer a research question. This can be done individually or as a group. Follow the flowchart on the Handout. This activity addresses the scientific method using already-collected data.

Extension Activities

Overview of Post-Field Trip Activities

Discussion Points: Wildland/Urban Interface, Climate Change and Fire, Fire Management Goals for the Future.

Use these background information sheets to introduce these important extension topics.

Writing About Future Landscapes.

Use this writing prompt in conjunction with **Climate Change and Fire** to get students thinking about how landscapes change over time.

Management Choices. Use **Management Choices Activity Sheet**, **Management Choices Area Cards**, and **Management Choices Handout.**

This activity addresses how different stakeholders feel about fire in their communities.

Independent Research Project. Use **Independent Research Project Activity Sheet** and **Independent Research Project Handout**.

Use this activity to explore more in-depth topics in fire ecology, either individually or as a group.

Fire Ecology Review Game.

This quick game will review fire basics and fire ecology.

Fire Catcher Activity Sheet.

In this short activity students will make an origami game to help reinforce important fire basics.

Wildland/Urban Interface

Fire is a natural component of almost every ecosystem on earth. That includes ecosystems where humans have made their mark by building structures, paving roads, and doing countless other things to rearrange nature. Many human-impacted areas are either situated in or near natural areas, including forestlands. In places like these, where nature and people overlap it is called the *Wildland/Urban Interface*. Here at Grand Canyon, many National Park Service buildings are located in or near wooded areas. This makes the community a beautiful and tranquil place to live and work, but also offers fire one of its three necessary components: fuel.

In very urban areas, fuels have been removed to a greater degree. In communities such as Grand Canyon, or any of thousands of woodland communities across the country, the threat of fire persists because the fuels have not been removed or heavily tamed.

Without some sort of fuel-clearing, many communities that live near natural areas might eventually be negatively affected by fire. But land managers and fire planners face difficult decisions about how to lessen the chance of negative-impact fires. As we now know, prescribed fire is one of the most effective ways to clear out fuels, but how many people enthusiastically advocate lighting fires near homes or other buildings? Other fuel-reduction choices are not nearly as effective, but seem “safer” than fire.

Land managers and fire planners have to be very sensitive to the needs of the community and the needs of the land, all while holding human safety as the number one priority. Sometimes they choose to light prescribed fires in hopes of a low intensity, fuel-clearing blaze, and sometimes they choose to not ignite. Whatever choices they make, it is important for us as community members to understand that fire is a force of nature, and as humans we will never be truly able to control it.

Extension Activities

Grand Canyon National Park Fire Program Goals

The first goal of the Grand Canyon Fire Program is to **keep park visitors and residents safe**. The Fire Management Program also lists four other goals:

1. Restore and maintain park ecosystems in a natural, resilient condition.

Return ecosystems to natural fire intervals, reduce fuels in the ecosystems, lessen the impact of non-native species, and reduce the impact of insect pests.

2. Protect the park's natural, cultural, and social resources.

Keep the ecosystems healthy in order to sustain threatened and endangered species, protect historical structures and artifacts from fire damage, maintain the integrity of soil and water, and minimize impacts of smoke in the canyon.

3. Implement a fire program based on the most current and best available scientific information.

Conduct research to understand fire regimes, refine fire prescriptions, and provide data for future fire prescriptions; monitor and evaluate fire management activities.

4. Educate, inform, consult, and collaborate with the public.

Discuss fire goals and plans with local Native American tribes and public and private stakeholders; educate the public about natural fire processes, fire goals, and management activities.

Extension Activities

Handout: Writing about Future Landscapes

Humans have been suppressing fires at Grand Canyon National Park since the early 1900s. This has caused some noticeable changes in the landscape. For example, ponderosa forests used to be much more open than they are today, with fewer young trees. This was because young trees were killed by frequent, low intensity fires.

1937, North Rim of Grand Canyon

When gathering data on plots, fire monitors always take a picture of the area to document what it looks like at a given date, and to track changes over time. Pictures of ecosystems from the past tell us that much has changed in a short time, and not just from fire suppression. Drought, warmer temperatures, and overgrazing have changed ecosystems as well.

If you could fast forward to 2100, what do you think the plots you observed might look like? How might these changes have affected other plants and animals in the area? Do you think these changes would be positive or negative?

Write to describe what you imagine the plot areas will look like and the potential effects on the rest of the ecosystem.

Activity: Management Choices

Lesson Overview

Students will decide how to treat fuel overloads in a given area.

Lesson Objectives

Students will understand the consequences of making fire management decisions and defend their chosen management plan.

Materials

- Laminated Management Choices Cards
- Handouts

Activity Length

30 Minutes

Procedure

1. Arrange students into groups. There should be no more than 6 students per group.

2. Assign each group a Management Choices card. The management area that students must make a decision about is **bolded**. For example, on Card 1, the **wooded area** around the houses, not the houses themselves, are what students must make a decision about.

3. Have students discuss their land management area. Establish its characteristics: Are there any structures? Wildlife habitats?

4. As a group, have students discuss the pros and cons of each management choice listed in their handout. Groups must decide on a course of action and be able to defend it (they can also create a new option that is not on the list… as long as they can support it!)

5. Reconvene and have a spokesperson from each group stand up and describe their area, which management plan they chose, and why.

Extension Activities

Activity: Management Choices

Handout: Management Choices

What can be done to lessen the threat of fire from fuel overload? Here are your choices- use the charts to discuss pros and cons and help you make a decision. Remember there is no “right” answer, but there could be negative effects… so think it through!

1. Non-fire fuel treatment. This course of action will not make use of fire. Instead, it will focus on thinning fuels by hand or by machines. Hand-thinning can include raking dead and downed fuels and transporting them to a power plant to be burned for energy. Mechanical thinning will use special machines to cut down and mulch up fuels, which will then be either re-deposited on the forest floor or transported out of the area for energy production or commercial processing (creating chipboard, paper, etc.)

Pros	Cons

2. Prescribed fire fuel treatment. A fire plan will be in place and staff will actively ignite prescribed fires, always taking into consideration safety and community protection.

Pros	Cons

Handout: Management Choices

3. Mixed fuel treatment program. A fire plan will be in place, and if any naturally caused fires ignite that fit into this plan they will be allowed to burn (as long as they are not endangering structures or other resources). No prescribed burns will be ignited by staff. Manual and mechanical thinning will also take place.

Pros	Cons

4. No action/fire suppression. No fire treatment or manual/mechanical thinning will take place. All human or naturally caused fires will be suppressed quickly.

Pros	Cons

Land Management Card:

Plan of Action:

1. Non-fire fuel treatment.

2. Prescribed fire fuel treatment.

3. Mixed fuel treatment program.

4. No action/fire suppression.

Why? Be specific!

Management Choices Land Area Cards

Instructions: Print single-sided, laminate, and cut out around boxes. Each group gets one card.

1. A suburban neighborhood surrounded by **many acres of woods**, separated from a larger town by a river. The last fire to burn through the woods was over 35 years ago. Fire ecologists say the fire interval (the amount of time between naturally occurring fires) for the forest type is about 10 years. No thinning has taken place and a county ordinance prohibits people from collecting firewood in the forest, even if it is downed. The year-round temperature averages about 72° F, and relative humidity is high.

2. A large **national forest** far from any town, with only a dozen structures (employee housing, maintenance, and offices). The forest is a mix of pinion pine and juniper trees, with sandy soils also supporting wildflowers, grasses and lots of small shrubby plants. The fire ecologist in the region says that this area usually burnt once every 100 years or so, but no one can tell you the last time a fire came through. This area is usually very hot and dry, with monsoon seasons bringing the only relief in the form of huge rain and lightning storms.

3. The most visited National Park in the country. It has a major highway running through it, which many locals use to get to work and shop in the nearby city. Lots of small towns surround the park, with many houses scattered in between towns and nestled back in the woods. The **forest within the park** is mixed-conifer, and has historically been quite open with few young trees. Park Service officials worry that too many young trees are crowding the forest. The park is at an elevation of 4000', surrounded by low-lying valleys on all sides. The area receives frequent rains.

4. A large state park near a heavily populated area. Nearby counties have been hit with frequent, high intensity fires in the last 5 years, but this park and the surrounding lands have not burned for at least a decade. This is a dry, warm area very close to the Mexican border. Strong winds often come down off the nearby mountains. The park is covered by mostly **grasslands and dwarfed trees**, but lately the grasses have begun to disappear and desert is taking their place. Ecologists warn that without fire, the soil is being depleted of its nutrients and can no longer support the native grass population.

5. A resort located in the Southwest, with many visitors every year. The area is dry and warm during the summer, with heavy snowfalls during the winter and into spring. Summer storms can bring lots of lightning. There are residential areas within the resort, and many business structures as well (some of them quite historical). The resort brings a lot of tourist money into the area, and this tourism is based on outdoor recreation. Some areas of the resort have been treated with prescribed fire in recent years, but the **wooded land around the structures** has not been burned since Europeans first started settling the area back in the late 1800s.

Activity: Independent Research Project

Lesson Overview

Students will research a fire ecology topic.

Lesson Objectives

Students will expand upon the topics introduced in pre-visit lessons and the field trip. They will research and write a report and present the information to the class.

Materials

- Access to the internet, a library, and/or fire professionals for interviews
- *Independent Research Project* Handouts
- *Teacher's Guide to Handout*
- *(Optional)* Microsoft PowerPoint and projector with screen

Activity Length

Variable

Procedure

Before assigning the project, decide:

a. How many pages the written reports should be, and what citation format should be used.
b. The format of the final presentation. Will it be a PowerPoint presentation? A quick overview in front of the class? A poster?

1. Use the *Independent Research Project* Handout to introduce the project. Give students time to brainstorm about research topics.

2. Assign deadlines to each of the steps on the handout. See attached *Teacher's Guide to Handout* for suggestions.

3. Verify student work on the assigned deadlines.

4. Schedule student presentations and collect final written reports.

Handout: Independent Research Project

1. Select a topic that interested you during our field trip or the pre-visit lessons. Examples include: Fire behavior, exotic plants and fire, soil and fire, etc.

Topic: ____

2. Make a list of key words that will help you research this topic.

Key Words: ____

3. Find sources of information about your topic. Make sure they are reputable! Websites should give you a good start to your research, but don't forget personal interviews and library books. Record these potential sources on a separate sheet of paper so you can come back to them.

4. Browse through your sources and start jotting down notes about the topic.

5. Come up with a specific question about your topic. For example, if you chose fire behavior, your question might be: *How does weather affect fire behavior?* It is okay to write down a few questions and refine them into one question later.

Question: ____

6. Now that you have a more focused research question, start reading your sources and taking more detailed notes. Make sure you record where your information is coming from so you can cite it later!

7. If necessary, revise your question(s).

Revised Question: ______________________________________

8. Keep taking notes until you have enough background information to answer your question.

9. Refine your question into a thesis statement. A thesis statement articulates *your opinionated response* to the question. Make sure your opinion is not just a guess- it should be based on the research you have done. Using the above question as an example again, your thesis statement might be: *High winds and low relative humidity combine to make fire spread faster.* As you can see, a thesis statement describes your position on the topic.

Handout: Independent Research Project

10. Think about the information you will need to present in order to persuade someone of your thesis position. Create a rough outline of the information you will need to cover in your report.

11. Fill in the outline with more and more details collected from your research. Make sure you record where the information is coming from. For now, these details don't have to be in complete sentences. Just try to give yourself a lot of information to work with when it comes time to…

12. Write the paper! You could start by turning all of your details into full sentences. Or, you could start with the opening paragraph and move on from there, if it helps you organize your thoughts. Either way, just starting writing!

13. As you are writing, cite your information. Use an accepted citation style, such as MLA.

14. Make sure your paper has a clear introduction and conclusion. Think of it this way:

Tell us what you are going to say *(introduction)***,**
Tell us what you are saying *(body)***,**
Tell us what you said *(conclusion)***!**

15. Re-read your paper at least twice and edit. The first time, read it for grammar and spelling mistakes. The second time, read it to answer the following questions:

Is my thesis statement supported by the information I have given in the body of the paper?

Does the 'flow' of the writing make sense? Do I need to re-arrange information?

If a person who knew nothing about my topic read this, would he or she be able to understand what I am talking about? Are there any gaps in information?

16. Have someone you trust read your paper. Ask them to give you honest feedback on it. It is up to you to accept their changes or not, but you should at least consider their suggestions. It is easy to get caught up in our own world when we are writing, and sometimes we can't read our own work with an objective eye. Use others to help you be a successful writer!

Fire Ecology Review Game and Answer Key

To play, copy cards single-sided and cut out. Match the cards: each question card should have an answer.

Answer Key:

Card 1– Card 19
Card 2– Card 27
Card 3– Card 23
Card 4– Card 17
Card 5– Card 30
Card 6– Card 18
Card 7– Card 22
Card 8– Card 26
Card 9– Card 16
Card 10– Card 29
Card 11– Card 28
Card 12– Card 21
Card 13– Card 25
Card 14– Card 20
Card 15– Card 24

It drops its lower branches as it grows, keeping its needles away from low flames. It also has very thick bark (up to 4 inches) that protects the cambium from fire’s heat.

1

What are some positive impacts fires can have on an ecosystem?

2

Fire can clear out brushy plants and shrubs and encourage grasses to grow, which are ideal for grazing animals.

3

How is a Ponderosa pine fire-adapted?

19

It can improve grazing habitat for large mammals, decrease non-native species populations, decrease the amount of fuel in an ecosystem, and enrich the soil by depositing nutrients back into it.

27

Native Americans once used fire to keep bison populations strong. How?

23

What makes a fire beneficial?

4

What three factors determine how fires behave?

5

What do you call a fire ignited to accomplish specific land management goals?

6

A beneficial fire will accomplish land management goals and help the ecosystem become healthier.

17

Topography, fuels, and weather.

30

A planned, or prescribed, fire.

18

What are some tools used to monitor weather?

7

Lightning.

8

What is fire ecology?

9

A sling psychrometer (to measure relative humidity), and an anemometer (to measure wind speeds).

22

What is one natural ignition source of wildland fires?

26

It is the study of how fire affects ecosystems.

16

Under what conditions are wildland fires more likely to occur?

10

What three things must be present for fire to burn?

11

An undesirable wildland fire is often called what?

12

Fires can occur more readily whenever it is hot and dry. They are especially likely during lightning season.

29

Oxygen, Fuel, and Heat.

28

An unplanned wildland fire.

21

How do animals survive wildland fires?

13

What are some negative impacts fire can have on an ecosystem?

14

Always drown, stir, and check campfires. Rake back small, light fuels away from campfire circles. Always have water on hand in case a campfire gets too big. Never let anyone throw cigarettes into forestland.

15

Larger animals and birds can flee. Smaller animals can burrow and wait until the fire passes- they will probably be protected by the layers of soil unless the fire is very intense. Micro-organisms and insect populations are less likely to survive because they cannot run away.

25

If fires burn too intensely, they can kill live trees by burning needles or leaves. Fires can harm animals unable to flee the fire. If a fire can't be contained, it has the potential for property destruction.

20

How can you help keep human-caused fires out of our forests?

24

Activity: Fire Catcher

To Fold:

1. Cut out the above large square.
2. Fold in half diagonally. Unfold. Fold in half on the other diagonal. Unfold so you are back to a square.
3. Fold each corner towards the center point (so that you create a smaller square).
4. Keeping the four corners folded in, flip the square over so you are looking at the back side.
5. Fold in these four corners to the center point. You should now have a smaller square with four flaps.
6. On these flaps write the following (doesn't matter which flap you start with):
   - Flap 1: What three broad factors influence fire behavior?
   - Flap 2: What aspects of topography affect fire behavior?
   - Flap 3: What aspects of fuel affect fire behavior?
   - Flap 4: What aspects of weather affect fire behavior?
7. Now flip each flap up one at a time so you are looking at a diamond. Write the answer to the question on the outside of the flap on the top half of the diamond.
8. After you are finished writing the answers to the questions, fold all the flaps back down so you have a square again.
9. Fold the square in half "hot dog style" so you have a rectangle. Insert fingers into pockets at bottom this rectangle.
10. Pop open the Fire Catcher. You will have four points facing you. Holding the Fire Catcher so it looks like a diamond, draw a triangle around the top three points. This will be your Fire Triangle. Label the three points with the three aspects of the Fire Triangle. The bottom point can be labeled Fire Catcher.

To Play:

1. Insert fingers into pockets at base of Fire Catcher. Have a partner pick a corner of the fire triangle. Move your fingers to fold and unfold the Fire Catcher back and forth as many times as there are letters in the chosen word (i.e., if Oxygen was chosen, the Catcher would be folded back and forth 6 times).
2. When you stop, have your partner pick a question. He or she must answer that question- check the answer on the inside flap!

Activity: Fire Catcher

Glossary

Adaptation: An evolved trait that helps a organisms survive and reproduce better than other organisms in an environment.

Aerial Fuels: All live and dead vegetation in the forest canopy, including tree branches, snags, and moss.

Aspect: The direction that a surface is facing.

Canopy: The cover formed by the upper branches of the trees in a forest.

Carbohydrate: A compound of carbon, hydrogen, and oxygen which is produced by green plants.

Carbon Dioxide: A gas produced by combustion as well as human respiration: CO_2.

Combustion: A chemical process that results from combining a fuel, heat source, and oxygen.

Crown: The leaves or needles and branches of a tree.

Crown Fire: Fire moving through the crowns of trees, more or less independently of a surface fire.

Dead Fuels: Fuels with no living tissue that gain moisture from their environment (relative humidity and precipitation) and lose it through solar radiation.

Duff: The layer of decomposing organic materials lying below the litter layer and above the mineral soil.

Fire Adaptation: An evolved trait that helps an organism survive fire better than other organisms in an environment, such as fire resistant bark.

Fire Behavior: How fire reacts to fuel characteristics, weather and topography.

Fire Ecology: The study of the relationship between fire and living organisms in an environment.

Fire Interval: The time in years between two fires in a given area.

Fire-Resistant Species: A species with characteristics that make it less likely to be injured or killed by fire.

Glossary

Flame: Gas-phase of fire.

Fuel: Combustible material.

Fuel Loading: The amount of fuel in a given area.

Fuel Reduction: Manipulation, including combustion or mechanical thinning, to remove fuels and reduce the chance of ignition.

Fuel Type: A description of fuels based on size and location within the forest.

Ground Fuel: All combustible materials below the surface litter, including duff and tree roots.

Ladder Fuels: Fuels that can carry flames from surface fuels into the crowns of trees or shrubs.

Litter: Top layer of the forest floor composed of loose dead sticks, twigs, and recently fallen leaves or needles.

Live Fuels: Plants with live tissues that actively gain water to support life function.

Planned/Prescribed Fire: A fire ignited by fire staff under predetermined conditions to meet specific goals, usually fuel reduction.

Prescription: Measurable criteria that define conditions under which a prescribed fire may be ignited.

Relative Humidity: The amount of water vapor in the air, expressed as a percentage of the maximum amount that the air could hold at the given temperature.

Snag: A standing dead tree that has lost many of its smaller branches.

Slope: The slant, or deviation from the horizontal, of a given area.

Solar Radiation: Energy from the sun, which is a combination of bright light and radiant heat.

Spot Fires: A small fire ignited by debris that has blown away from a larger fire and then ignited a new area of fuels.

Glossary

Stand Replacement Fires: A fire that kills many of the large organisms in an area and dramatically changes the structure of the ecosystem.

Succession: The gradual change of a plant community. After a severe (stand-replacement) fire, succession often occurs in this order: herbaceous plants (grasses and wildflowers) emerge first, then shrubs and small trees begin to grow, and then the dominant woody plant emerges. Plants that grow first after a fire often die out to make way for new plants. In low intensity fires, succession is often less dramatic.

Surface Fire: A fire that burns in the litter layer and other fuels on the surface of the ground.

Surface Fuels: Loose surface litter consisting of fallen leaves or needles, twigs, bark, cones, and small branches, as well as grasses, shrubs, tree seedlings, logs, and stumps.

Ten o'clock rule: A fire management policy implemented in the 20th century stating that all fires must be extinguished by 10 o'clock a.m. the day after ignition.

Terrain: The physical features of a tract of land.

Topography: The natural features of an area, including elevation changes and other characteristics.

Unplanned Wildland Fires: Wildland fires ignited by natural (lightning or volcanoes) sources, or human-caused wildland fires that are unauthorized or accidental.

Virga: Precipitation that evaporates before hitting the ground.

Wildland Fire: Any fire that occurs outside a building. A fire burning in grasslands, shrubs, or forests.

Wildland/Urban Interface: The area where human development meets undeveloped wildland.

Reference

Arizona State Standards Addressed

Introduction

Strand 2 Concept 1 *PO 3*. Analyze how specific changes in science have affected society.
Strand 3 Concept 1 *PO 1.* Evaluate how the processes of natural ecosystems affect, and are affected by, humans.
Strand 3 Concept 1 *PO 2.* Describe the environmental effects of the following natural and/or human-caused hazards: flooding, drought, earthquakes, **fires**, pollution, and extreme weather.
Strand 3 Concept 1 *PO 3.* Assess how human activities (e.g., clear cutting, water management, tree thinning) can affect the potential for hazards.

Activity: Weather and Fuels

Strand 1 Concept 1 *PO 4.* Predict the outcome of an investigation based on prior evidence, probability, and/or modeling (not guessing or inferring).
Strand 1 Concept 2 *PO 1.* Demonstrate safe and ethical procedures (e.g., use and care of technology, materials, organisms) and behavior in all science inquiry.
Strand 1 Concept 2 *PO 5.* Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs, and computers.
Strand 3 Concept 1 *PO 2.* Describe the environmental effects of the following natural and/or human-caused hazards:

- flooding
- drought
- earthquakes
- **fires**
- pollution
- extreme weather

Strand 5 Concept 4 *PO 2.* Identify the indicators of chemical change, including formation of a precipitate, evolution of a gas, color change, absorption or release of heat energy.
Strand 5 Concept 4 *PO 3.* Represent a chemical reaction by using a balanced equation.

Activity: Topography and Fuel Density

Strand 1 Concept 1 *PO 3.* Formulate a testable hypothesis.
Strand 1 Concept 2 *PO 1.* Demonstrate safe and ethical procedures (e.g., use and care of technology, materials, organisms) and behavior in all science inquiry.
Strand 1 Concept 2 *PO 5.* Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs, and computers.
Strand 3 Concept 1 *PO 3.* Assess how human activities (e.g., clear cutting, water management, tree thinning) can affect the potential for hazards.

Arizona State Standards Addressed

Activity: Fire and the Web of Life

Strand 3 Concept 1 *PO 2*. Describe the environmental effects of the following natural and/or human-caused hazards:
• flooding
• drought
• earthquakes
• **fires**
• pollution
• extreme weather
Strand 4 Concept 3 *PO 1.* Identify the relationships among organisms within populations, communities, ecosystems, and biomes.
Strand 4 Concept 3 *PO 2.* Describe how organisms are influenced by a particular combination of biotic (living) and abiotic (non-living) factors in an environment.
Strand 4 Concept 4 *PO 3.* Describe how the continuing operation of natural selection underlies a population's ability to adapt to changes in the environment and leads to biodiversity and the origin of new species.
Strand 4 Concept 5 *PO 4.* Diagram the energy flow in an ecosystem through a food chain.

Activity: Introduction to Two Ecosystems of Grand Canyon

Strand 1 Concept 2 *PO 5.* Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs, and computers.

Activity: Adaptation Derby

Strand 1 Concept 1 *PO 1.* Evaluate scientific information for relevance to a given problem.
Strand 1 Concept 2 *PO 1.* Demonstrate safe and ethical procedures (e.g., use and care of technology, materials, organisms) and behavior in all science inquiry.
Strand 1 Concept 2 *PO 5.* Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs, and computers.
Strand 4 Concept 4 *PO 1.* Identify the following components of natural selection, which can lead to speciation:
• potential for a species to increase its numbers
• genetic variability and inheritance of offspring due to mutation and recombination of genes
• finite supply of resources required for life
• selection by the environment of those offspring better able to survive and produce offspring

Reference

Arizona State Standards Addressed

Strand 4 Concept 4 *PO 3*. Describe how the continuing operation of natural selection underlies a population's ability to adapt to changes in the environment and leads to biodiversity and the origin of new species.

Activity: Geocaching

Strand 1 Concept 2 *PO 1*. Demonstrate safe and ethical procedures (e.g., use and care of technology, materials, organisms) and behavior in all science inquiry.

Landscape Change in the Future Writing Activity

Strand 1 Concept 2 *PO 5.* Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs, and computers.
Strand 3 Concept 1 *PO 1.* Evaluate how the processes of natural ecosystems affect, and are affected by, humans. **Strand 3 Concept 1** *PO 2.* Describe the environmental effects of the following natural and/or human-caused hazards:
• flooding
• drought
• earthquakes
• **fires**
• pollution
• extreme weather
Strand 3 Concept 1 *PO 3.* Assess how human activities (e.g., clear cutting, water management, tree thinning) can affect the potential for hazards.

Independent Research Activity

Strand 1 Concept 1 *PO 1.* Evaluate scientific information for relevance to a given problem.
Strand 1 Concept 2 *PO 5*. Record observations, notes, sketches, questions, and ideas
Strand 1 Concept 4 *PO 3.* Communicate results clearly and logically.
Strand 1 Concept 4 *PO 4.* Support conclusions with logical scientific arguments.
using tools such as journals, charts, graphs, and computers.
Strand 3 Concept 1 *PO 3.* Assess how human activities (e.g., clear cutting, water management, tree thinning) can affect the potential for hazards.
Strand 3 Concept 2 *PO 2.* Recognize the importance of basing arguments on a thorough understanding of the core concepts and principles of science and technology.
Strand 3 Concept 2 *PO 3.* Support a position on a science or technology issue **Strand 3 Concept 2** *PO 5.* Evaluate methods used to manage natural resources (e.g., reintroduction of wildlife, fire ecology).

Reference

Arizona State Standards Addressed

Strand 4 Concept 4 *PO 4.* Predict how a change in an environmental factor (e.g., rainfall, habitat loss, non-native species) can affect the number and diversity of species in an ecosystem.

Field Experience

Strand 1 Concept 1 *PO 3.* Formulate a testable hypothesis.
Strand 1 Concept 2 *PO 1.* Demonstrate safe and ethical procedures (e.g., use and care of technology, materials, organisms) and behavior in all science inquiry.
Strand 1 Concept 2 *PO 5.* Record observations, notes, sketches, questions, and ideas using tools such as journals, charts, graphs, and computers.
Strand 1 Concept 2 *PO 6.* Conduct a scientific investigation that is based on a research design
Strand 1 Concept 3 *PO 1.* Interpret data that show a variety of possible relationships between variables, including: positive relationship negative relationship no relationship.
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Analyzing Plot Data

Strand 1 Concept 3 *PO 1. Interpret data that show a variety of possible relationships between variables, including: positive relationship negative relationship no relationship.*
Strand 1 Concept 3 *PO 4.* Evaluate the design of an investigation to identify possible sources of procedural error, including:
• sample size
• trials
• controls
• analyses
Strand 1 Concept 3 *PO 6.* Use descriptive statistics to analyze data, including:
• mean
• frequency
• range
Strand 1 Concept 3 *PO 7.* Propose further investigations based on the findings of a conducted investigation.
Strand 3 Concept 1 *PO 5.* Evaluate the effectiveness of conservation practices and preservation techniques on environmental quality and biodiversity.
Strand 3 Concept 2 *PO 5.* Evaluate methods used to manage natural resources (e.g., reintroduction of wildlife, **fire ecology**).

Activity: Management Choices

Strand 3 Concept 1 *PO 1.* Evaluate how the processes of natural ecosystems affect, and are affected by, humans.

Reference

Arizona State Standards Addressed

Strand 3 Concept 1 *PO 2.* Describe the environmental effects of the following natural and/or human-caused hazards:

- flooding
- drought
- earthquakes
- **<u>fires</u>**
- pollution
- extreme weather

Strand 3 Concept 1 *PO 4.* Evaluate the following factors that affect the quality of the environment:

- urban development
- **<u>smoke</u>**
- volcanic dust

Strand 3 Concept 2 *PO 5.* Evaluate methods used to manage natural resources (e.g., reintroduction of wildlife, fire ecology).

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